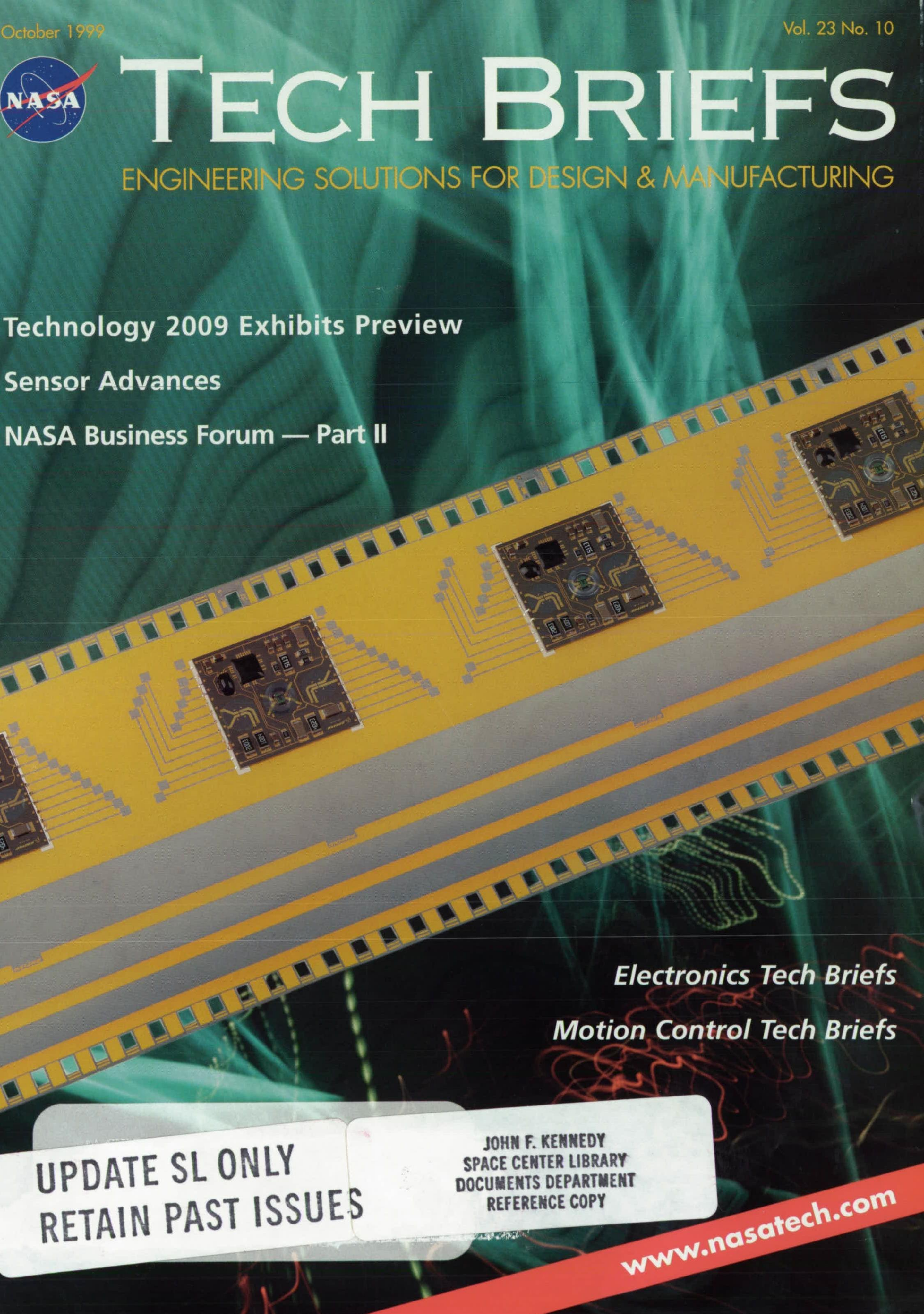
October 1999
Vol. 23 No. 10

TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING



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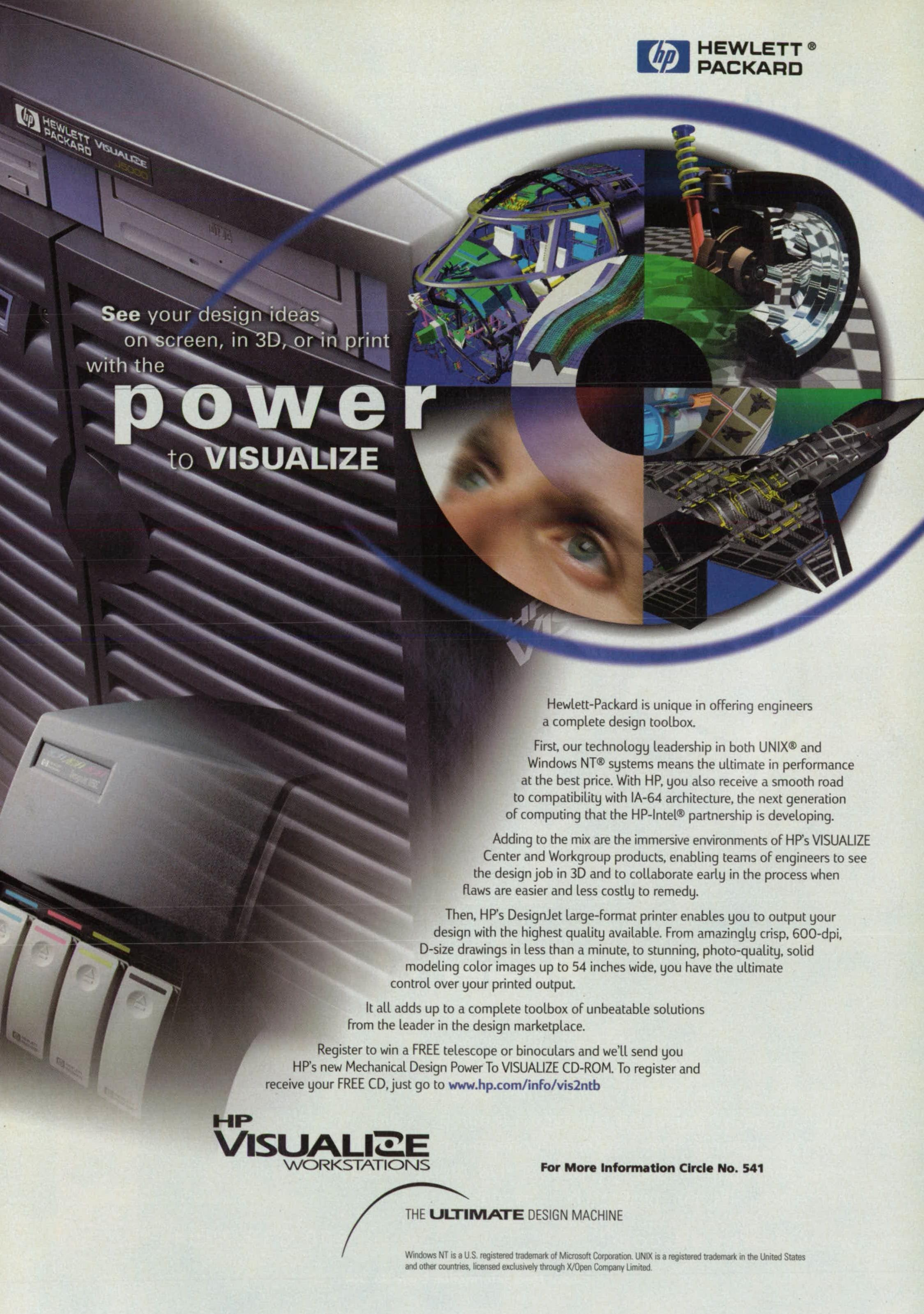
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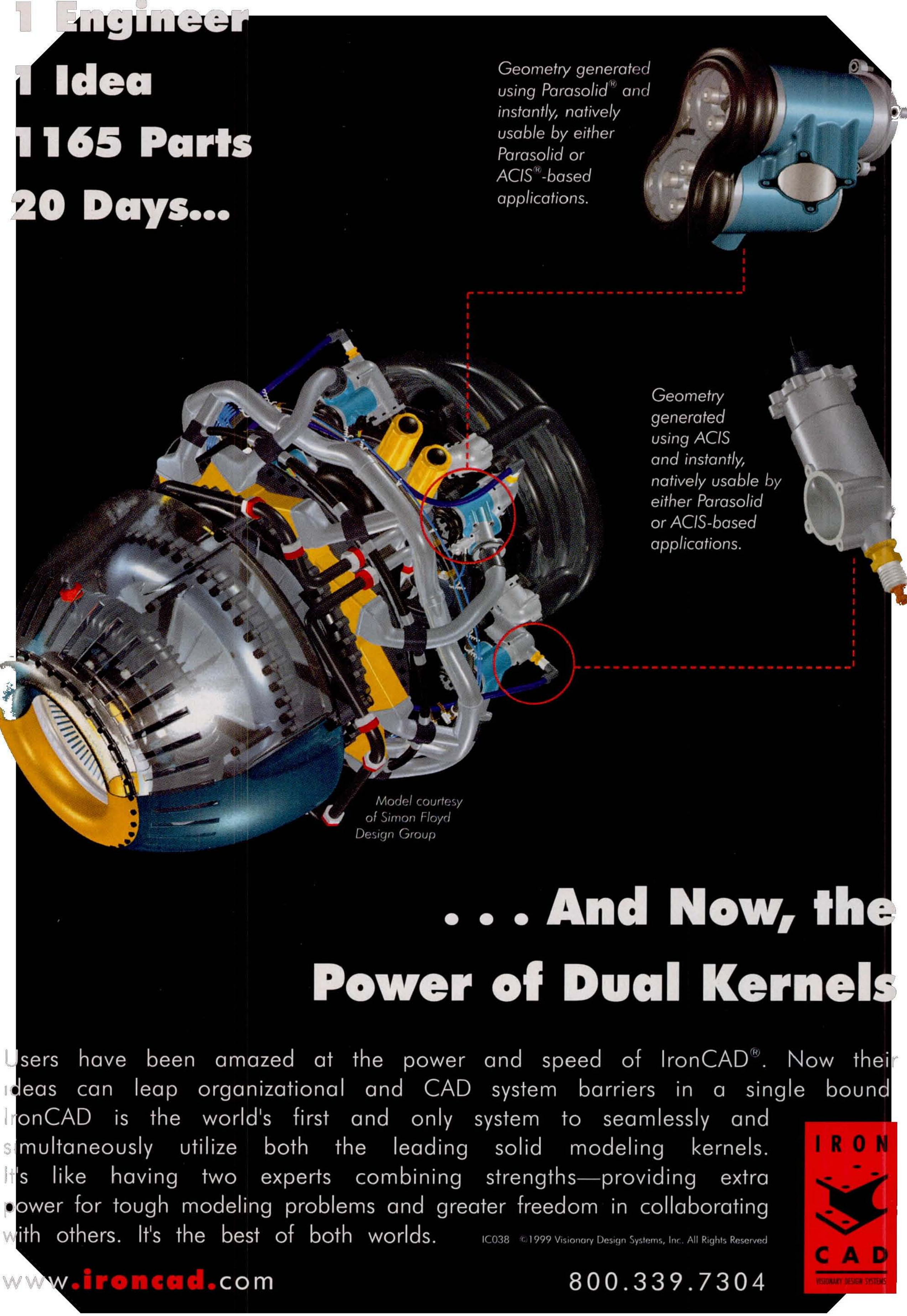
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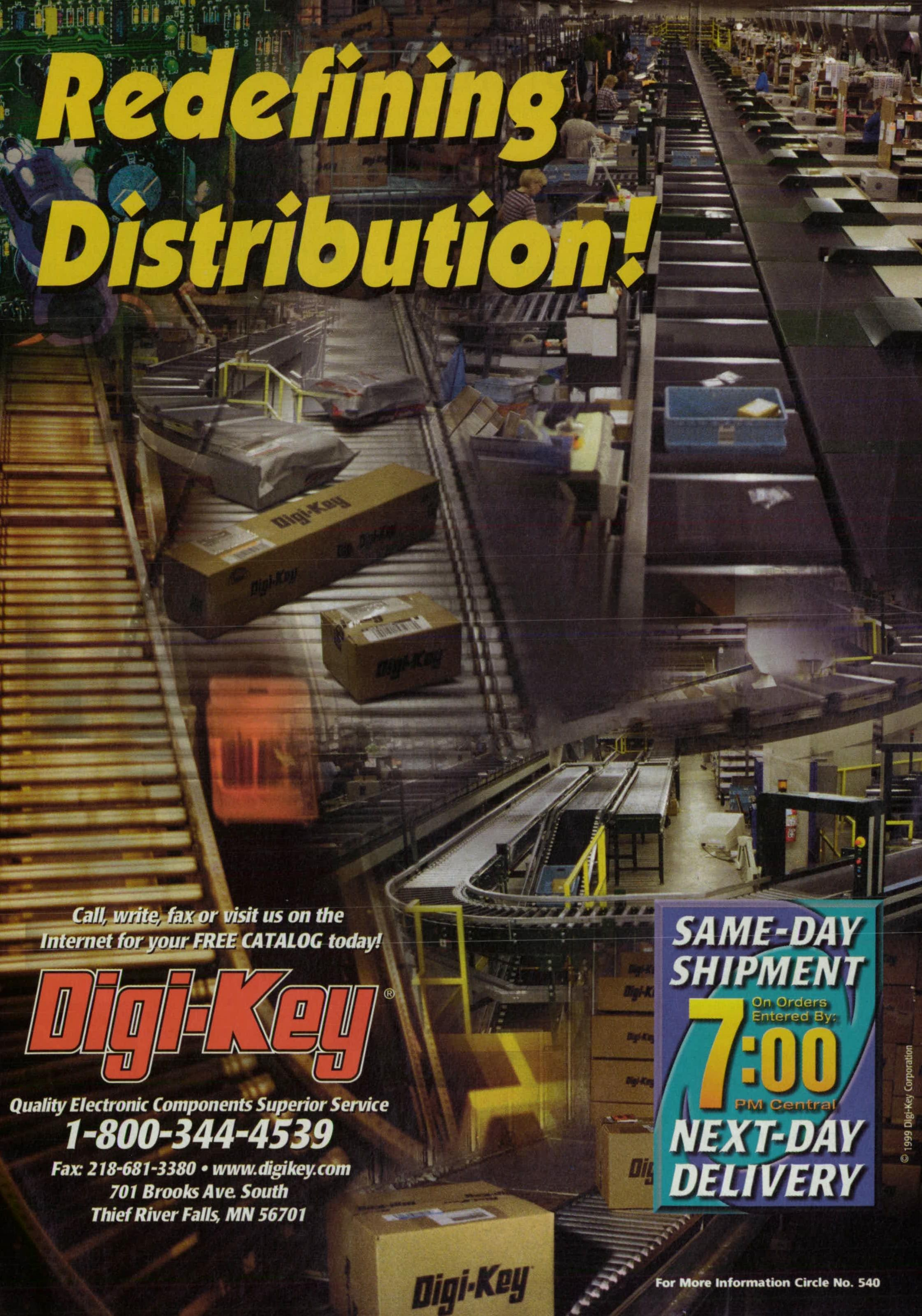
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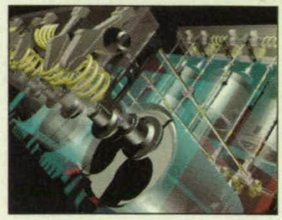

ON THE COVER

Endevco Corp. (San Juan Capistrano, CA) and Boeing have developed a state-of-the-art smart sensor network system that provides multi-point pressure measurements using low-profile transducers and electronics attached to a uniquely configured pressure belt. The belt incorporates Endevco's MEMS silicon sensors used for flight load testing. Boeing is using the new system to measure pressure at multiple points on the skin of aircraft. For more information on the pressure belt technology, see the Special Coverage Feature on Sensors beginning on page 72.

(Image courtesy of Endevco Corp.)

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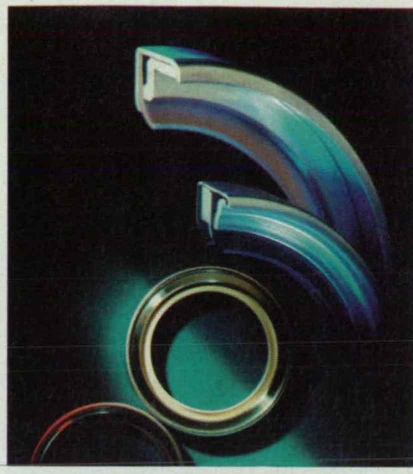

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Three spring-energizer designs make the Turcon® Variseal™ more versatile.

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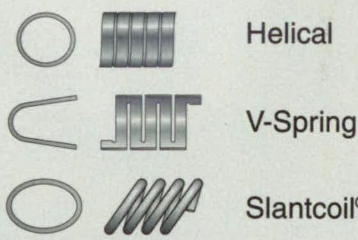

Choosing the right spring is a critical step in the design process. The Helical Spring applies the highest unit load, making it an excellent choice for static and slow-speed reciprocating applications. For high-speed reciprocating, or moderately fast rotary applications, the V-Spring is a better choice. This spring is also used for applications with abrasive environments where superior scraping is critical.

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BRIEFS & SUPPORTING LITERATURE: Written and produced for NASA by **Advanced Testing Technologies, Inc.,** Hauppauge, NY 11788
Technical/Managing Editor .... **Ted Selinsky**
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Staff Writers/Editors .... **Dr. Theron Cole, George Watson**
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NASA Tech Briefs are provided by the National Aeronautics and Space Administration, Technology Transfer Division, Washington, DC:
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NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (609) 667-7737 for the FLC coordinator in your area.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center
Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
Carolina Blake
(650) 604-0893
cblake@mail.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Lee Duke
(805) 258-3802
lee.duke@dfrc.nasa.gov

Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Command.
George Alcorn
(301) 286-5810
galcorn@gsfc.nasa.gov

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
Merle McKenzie
(818) 354-2577
merle.mckenzie@ccmail.jpl.nasa.gov

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Hank Davis
(281) 483-0474
hdavis@gp101.jsc.nasa.gov

Kennedy Space Center
Selected technological strengths: Command, Control, and Monitoring Systems; Range Systems, Fluids and Fluid Systems; Materials Evaluation and Process Engineering.
Gale Allen
(407) 867-6226
gale.allen-1@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Dr. Joseph S. Heyman
(757) 864-6006
j.s.heyman@larc.nasa.gov

John H. Glenn Research Center at Lewis Field
Selected technological strengths: Aeropropulsion; Communications; Energy Technology; High Temperature Materials Research.
Larry Viterna
(216) 433-3484
cto@grc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Sally Little
(256) 544-4266
sally.little@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Kirk Sharp
(228) 688-1929
ksharp@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

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NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

Carl Ray
Small Business Innovation Research Program (SBIR) & Small Business Technology Transfer Program (STTR)
(202) 358-4652
cray@mail.hq.nasa.gov

Dr. Robert Norwood
Office of Aeronautics and Space Transportation Technology (Code R)
(202) 358-2320
rnorwood@mail.hq.nasa.gov

John Mulcahy
Office of Space Flight (Code MP)
(202) 358-1401
jmulcahy@mail.hq.nasa.gov

Gerald Johnson
Office of Aeronautics (Code R)
(202) 358-4711
g_johnson@aeromail.hq.nasa.gov

Bill Smith
Office of Space Sciences (Code S)
(202) 358-2473
wsmith@sm.ms.ossa.hq.nasa.gov

Roger Crouch
Office of Microgravity Science Applications (Code U)
(202) 358-0689
rcrouch@hq.nasa.gov

Granville Paules
Office of Mission to Planet Earth (Code Y)
(202) 358-0706
gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

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Lewis Incubator for Technology
Cleveland, OH
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San Jose, CA
(408) 557-6700

Marty Kaszubowski
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(757) 865-2140

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.

Reader Forum

Reader Forum is devoted to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a specific technical problem, or an answer to a question that appeared in a recent issue, send your letter to the address below.

I am looking for a standards association or an organization that serves as a collection point of information on analog to digital converter cards for computer systems. I'd like to know a bit more about different vendors. Thank you for any assistance.

Robert Current
rob@current.nu

Thank you to NASA Tech Briefs *for the article on the ProSEDS tethered satellite project in your June issue ("Tethered Transportation," pg. 16). The endmass for that mission is being completely designed and manufactured by students of the University of Michigan, Ann Arbor College of Engineering. We have recently received full authorization from NASA to commence the construction of the endmass, which we've named ICARUS. This student group is composed of the best and brightest the University can offer, with most of us working as volunteers. We are on schedule and on budget to produce the needed satellite. The project is under the guidance of Dr. Brian Gilchrist at U of M.*

B.T. Cesul
Member, ICARUS Endmass Team
University of Michigan-Ann Arbor
btcesul@engin.umich.edu

*(**Editor's Note:** Thanks for your update on ProSEDS — Propulsive Small Expendable Deployer System — a propellant-free space propulsion system that operates via a tether. The ICARUS endmass and the ProSEDS project itself are funded by NASA's Marshall Space Flight Center in Huntsville, AL. Readers can obtain more information on ICARUS by contacting Dr. Brian Gilchrist of the University of Michigan-Ann Arbor at 734-936-0511; e-mail: brian.gilchrist@umich.edu)*

I believe I may have a solution for Gene Trower, who commented in July's Reader Forum about a fabric that would wick moisture away from the body. AlliedSignal in New York makes a product called Hydrofil Nylon, which manages moisture in four ways: absorption, adsorption, wicking, and drying. Another product that may be better suited for Mr. Trower's purpose is called Aerospacer Dri-Lex, which is the only three-zone, moisture-moving lining. AlliedSignal can be contacted at 800-695-5969; www.alliednylon.com.

William Nesbit
Defense Logistics Agency
wnesbit@dcc.dla.mil

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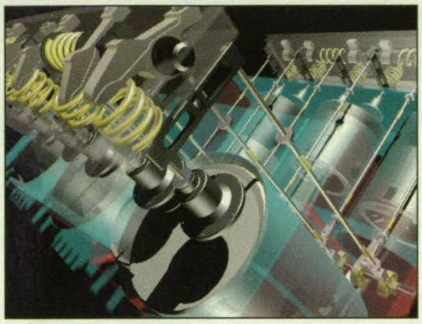
UpFront

PRODUCT OF THE MONTH



Spatial, Boulder, CO, has announced 3Dmodelserver.com™, a Web-based software application for repairing and improving 3D models. The application provides engineers with a solution that enables the use of models across multiple, heterogeneous software applications, making them more usable in design, analysis, and manufacturing. It minimizes the task of manually fixing errors found in translated models. Anyone with a Web browser and Internet connection can access the service, which can be updated on a daily basis. Powered by the ACIS® 3D Toolkit™ and Spatial's healing and translation technologies, 3Dmodelserver.com allows users to upload IGES models generated by virtually any CAD/CAM/CAE system, and ACIS SAT™ models generated by any of the ACIS-enabled application seats. Pricing is based on a cost-per-model transaction; users pay only for successful transactions.

For More Information Circle No. 750

NASA Studies Yellowstone

NASA's Stennis Space Center in Mississippi, along with Yellowstone Ecosystem Studies (YES) of Bozeman, MT, is evaluating two new NASA-developed remote sensing instruments that will fly over YES research sites in Yellowstone National Park to gain insight into key ecological processes in the Park.

Stennis' Commercial Remote Sensing Program is coordinating the project, which also includes NASA's Jet Propulsion Laboratory (JPL) in California. Researchers from YES, NASA, and Montana State University will compare imagery from the new sensors with other recent data sets of the Park, as well as field data gathered by the three organizations.

The new technology will help YES researchers answer questions pertaining to streams, wildlife habitat, and forest health. Projects of this type are essential to NASA in its design of new satellite remote sensing systems such as Landsat. This new project will assess how well data from the new sensors can be used in conjunction with hyperspectral data.

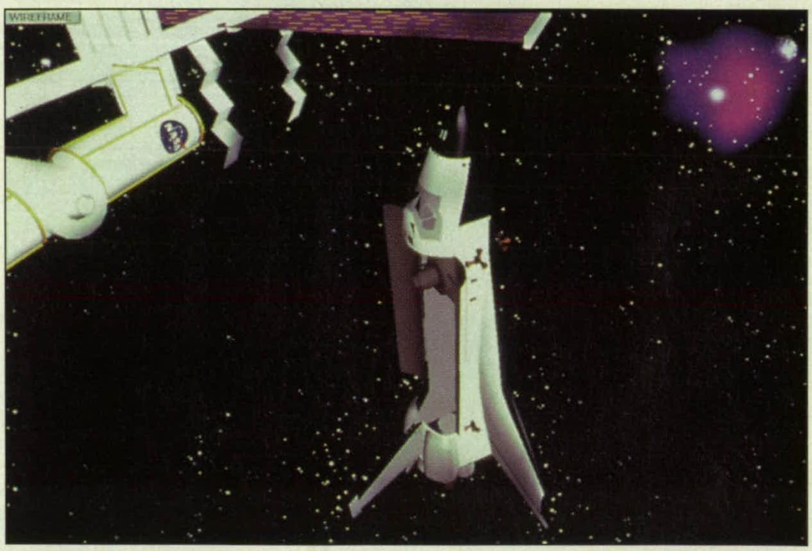
For more information, contact Stennis' Commercial Remote Sensing Program at 228-688-2042, or contact Montana State University's MSU TechLink at 406-994-7704.

Safer Docking

Researchers at NASA's Ames Research Center's Smart Systems Group in California have developed a 3D interactive space shuttle/space station docking simulation using WorldToolKit software from Engineering Animation of Ames, IA, and MATLAB software from The MathWorks of Natick, MA. The simulation is a preliminary step of the design phase for a "smart controller," a computerized joystick control with various types of feedback that can potentially aid in safer and more efficient docking of the shuttle to the International Space Station.

NASA is developing the project to improve the safety, accuracy, and efficiency of spacecraft docking. The Ames Smart Systems Group is addressing these problems by applying neurocontrol technologies that can learn, in near real-time, changes in spacecraft properties and performance characteristics.

"With the technology we've developed, we can avoid many of the challenges experienced in the 1997 Mir Space Station docking accident," said Dr. Robert Mah, senior scientist at NASA's Smart Systems Group. MATLAB is used for algorithm development, and WorldToolKit is used for 3D animation.



The simulated docking is guided by computerized joystick control, which can "learn" the behavior of the shuttle under different conditions, and use the information to dock it safely.

For more information, visit the NASA Ames Smart Systems Group web site at http://ssg.arc.nasa.gov; Engineering Animation at www.eai.com; and The MathWorks at www.mathworks.com.

NASA Patents

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

Environmentally Friendly Anti-Icing

(U.S. Patent No. 5,772,912)

Inventors: Robert T. Lockyer, John Zuk, and Leonard A. Haslim, Ames Research Center

The patent covers an aqueous, nonelectrolytic, essentially nontoxic, easily biodegradable, environmentally benign continuous-phase liquid composition for use as an anti-icing or deicing agent for the surfaces of aircraft, airport pavements, roadways, bridges, nautical components, railroad switches, motor vehicles, and other objects. The composition includes water, a nontoxic freezing point depressant, at least one nontoxic thickener, *e.g.*, a sugar, one or more optional environmentally benign corrosion inhibitors or surfactants, optional monohydric aliphatic unbranched alcohol, and an optional coloring agent. The thickener is a xanthan selected to impart viscosity thickening when dispersed or hydrated in the aqueous media, resulting in a composition with the properties of non-Newtonian pseudoplastic rheological behavior in which the near-static viscosity exceeds 20,000 cps at temperature ranges of about -30 °C and 0 °C. This produces a fluid protective barrier to ice accretion that is very durable and long-lasting.

Thermally Stable, Piezoelectric and Pyroelectric Polymeric Substrates

(U.S. Patent No. 5,891,581)

Inventors: Joycelyn O. Simpson and Terry L. St. Clair, Langley Research Center

Production of an electric voltage in response to mechanical excitation (piezoelectricity) or thermal excitation (pyroelectricity) requires a material to have a preferred dipole orientation in its structure. For some materials, a combination of mechanical and electrical orientation is necessary to completely polarize the material. Such is the case with the only commercially available piezoelectric polymer, poly(vinylidene fluoride) (PVF_2).

By the present invention thermally stable piezoelectric and pyroelectric polymeric substrates were prepared that retain their orientation, piezoelectric and pyroelectric properties at temperatures greater than about 100 °C. The substrates comprise a polymeric substrate with a softening temperature above 100 °C, a metal electrode deposited onto the substrate, and a polar field applied to the electrode to induce polarization. The devices have an advantage over piezoelectric inorganic materials because they are easily processable and conformable to a variety of different shapes. They can be used as electromechanical or thermomechanical transducers, accelerometers, and a variety of sensors.

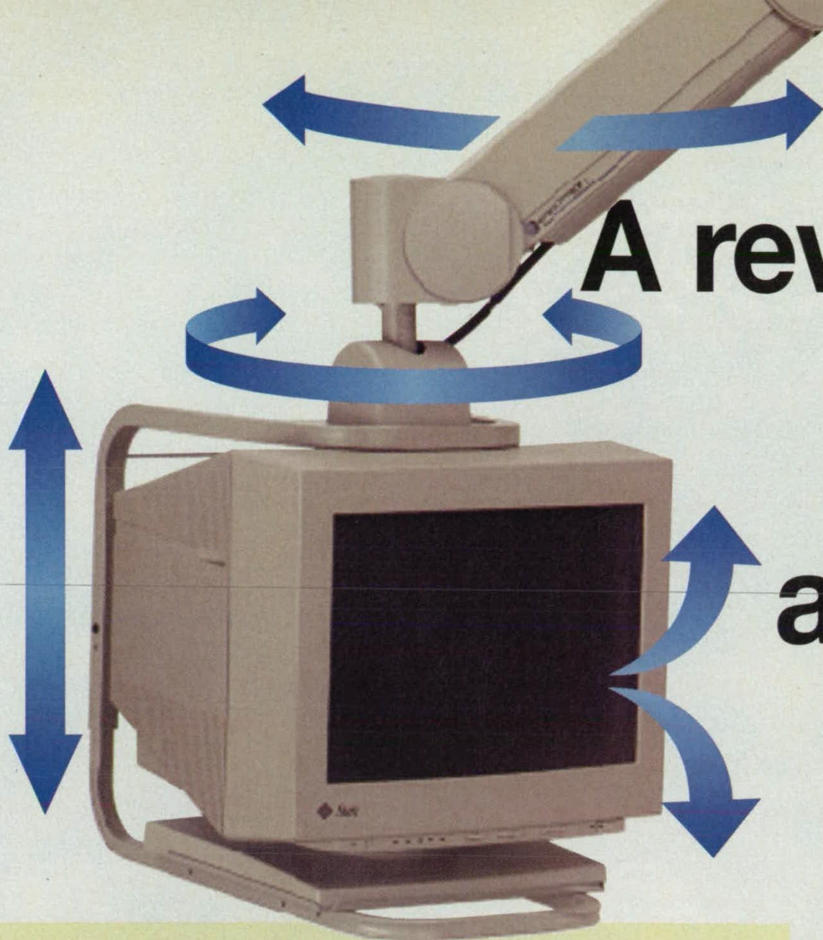
Nonintrusive Cable Tester

(U.S. Patent No. 5,894,223)

Inventors: Pedro J. Medelius and Howard J. Simpson, Kennedy Space Center

When troubleshooting a potential instrumentation problem on the space shuttle, personnel frequently have to demate cables to verify that they are not the problem's source. But once a cable is demated, any dedicated signal conditioners and other systems having a wire passing through the cable's connector have to be retested after the cable is reconnected. A system that allows cable continuity to be checked nonintrusively without demating would save many hours of testing and substantially reduce costs. The patent describes a cable tester using a bandpass filter with a very narrow bandwidth to eliminate noise and a signal detector to detect a test signal. By coupling a low-frequency test signal to one end of a cable under test, transmitting the signal along a length of the cable, detecting the signal along the length, and filtering the detected signal with the filter centered substantially at the signal's frequency, one can detect the presence or absence of the signal. When a short or open circuit causes the pickup coil to lose the test signal as it passes the fault, the absence of the signal indicates the location of the problem.

For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. *See page 12 for a list of office contacts.*



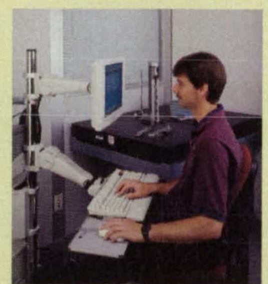
A revolutionary turn in industrial automation efficiency.

The economics of Ergotronics

Pivotal points

Provide user friendly and ergonomically designed operator accessibility to control and monitor machines, process lines and automated assembly operations.

Support multiple locations with a Mobile WorkStand solution.



Computer accessibility while maximizing plant floor workspace.

Bring computer peripherals directly to the "point-of-use".

Time is money. Space is a premium. Efficiency is productivity.

That's why Ergotron computer mounting systems maximize the effectiveness of computer hardware and the people who use it. We help you position plant floor computer networks where they work best. In terms of dollars per square foot. Time-motion efficiency. Accessibility. Even repetitive motion considerations.

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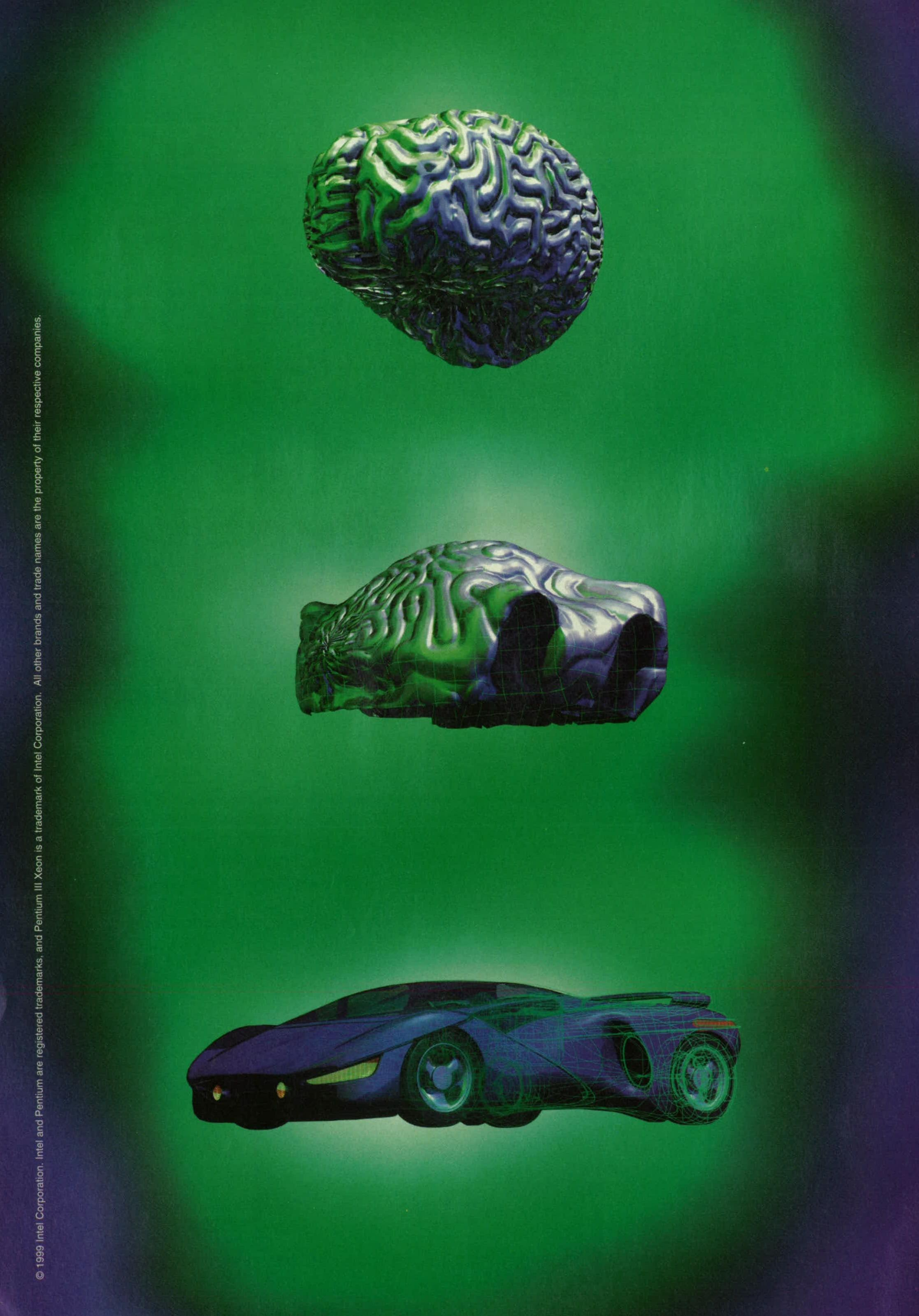
For More Information Circle No. 579



TECH EAST '99

EXHIBITS PREVIEW

Tech East '99 is the premier new technology showcase that comprises three exhibitions: **Technology 2009:** the Engineering Innovation Show, **Southeast Design & Manufacturing Expo,** and the **Small Business Tech Expo.** Tech East, sponsored by NASA, *NASA Tech Briefs*, Hewlett-Packard, and the Federal Laboratory Consortium, will be held November 1-3 at the Fontainebleau Hilton Hotel in Miami Beach. Following is a preview of the exhibitors you'll see displaying the latest in electronics, mechanics, materials, manufacturing, software, and R&D innovations. Visit **www.techeast.net** for the most current exhibitor list and registration details.

Booth numbers are preceded by a code indicating the show in which each company will be exhibiting:

T9 = Technology 2009
T9SBIR = Technology 2009 Small Business Innovation Research Pavilion
T9Lit = Technology 2009 Literature Exhibit
SEDME = Southeast Design & Manufacturing Expo
SBTE = Small Business Tech Expo
IEP = International Export Pavilion, Sponsored by *Commercial News USA*

Aerospace Design & Development — **T9 Booth 528**
Niwot, CO
Circle No. 699

AET — **T9SBIR Booth T10**
Melbourne, FL
Circle No. 698

AM-Appliance Manufacturer Magazine — **T9Lit Booth L4**
Solon, OH
AM-*Appliance Manufacturer* provides ideas to solve design and manufacturing problems, and addresses the concerns of the cross-functional design (CFD) teams in the global consumer, commercial, business, and medical-appliance industries.
Circle No. 697

Army Research Laboratory — **SEDME Booth 313**
Adelphi, MD
The Army will showcase intellectual property ready for licensing from both basic and applied research laboratories.
Circle No. 696

Austrian Trade Commission — **T9 Booth 418**
New York, NY
The Austrian Trade Commission promotes trade and mutual cooperation between the US and Austria, and helps identify market opportunities, technology transfers, and similar arrangements.
Circle No. 695

Bell Additives — **IEP Table T49**
Longwood, FL
Bell Additives blends high-quality gasoline and diesel additives as well as oil additives.
Circle No. 694

BMDO — **SBTE Booth 211**
Bethesda, MD
Circle No. 693

BVQI (NA) — **T9 Booth 429**
Jamestown, NY
Circle No. 692

Calorique — **IEP Table T46**
West Wareham, MA
Circle No. 691

CCS of Florida — **IEP Table T44**
Miami, FL
Circle No. 690

Centro Estero Camere Commercio Piemontesi — **T9 Booth 425**
Torino, Italy
The firm assists Piedmontese companies in finding trade and technology transfer opportunities abroad, and the converse.
Circle No. 689

CeramTec North America **SEDME Booth 317**
Laurens, SC
CeramTec is a subsidiary of CeramTec AG Innovative Ceramic Engineering, a technical ceramics engineering firm. CeramTec provides ceramic components for various applications.
Circle No. 688

Command and Control Technologies **T9 Booth 624**
Titusville, FL
This space-software company specializes in launch-site automation systems, including launch control and sequencing, range safety, range operations, portable payload processing, mission planning, and spaceport operations.
Circle No. 687

CoreTek **T9SBIR Table T14**
Wilmington, MA
CoreTek has introduced a commercially available implementation of a single-mode VCSEL operating in the 1550nm range. It is based on an implementation of MEMS (micro-electromechanical) technology. The MEMS structure forms the top mirror of the laser and movement of the mirror changes the cavity length of the laser, thus changing the emitted wavelength.
Circle No. 763

Design Automation **SEDME Booth**
Raleigh, NC
Circle No. 686

Diversified Technologies **T9SBIR Table T5**
Bedford, MA
Circle No. 685

Dolch Computer Systems **T9 Booth 412**
Fremont, CA
Circle No. 611

Electron Power Systems **SBTE Booth 223**
Acton, MA
The company will exhibit energy-storage and propulsion R&D services based on the newly discovered stable plasma technology that stores large amounts of energy as magnetic-field energy with virtually no mass.
Circle No. 682

Emcore Corporation **SBTE Booth 210**
Somerset, NJ
Emcore is a materials science company in the field of compound semiconductors. The company's divisions cover production systems and materials processes, epitaxial wafer foundry, semiconductor devices, VCSEL components and arrays, solar cell manufacturing, and R&D.
Circle No. 681

Enterprise Development Corp of South Florida **SBTE Booth 226**
Fort Lauderdale, FL
EDC provides business services such as strategic development and implementation, product commercialization, and access to capital funds. Also featured will be TechExchange Online, an e-commerce technology transfer site.
Circle No. 680

FAA Technology Transfer Office **T9 Booth 517**
Atlantic City, NJ
The Federal Aviation Administration (FAA) will focus on aviation system safety, and on the future of general aviation, including the FAA/NASA program called AGATE.
Circle No. 679

FARO Technologies **T9 Booth 520**
Lake Mary, FL
The Faro Arm and AnthroCam product family is specifically designed to close the gap between engineering and the manufacturing floor. Products include six different software programs designed to answer the questions that cost manufacturers time and money.
Circle No. 678

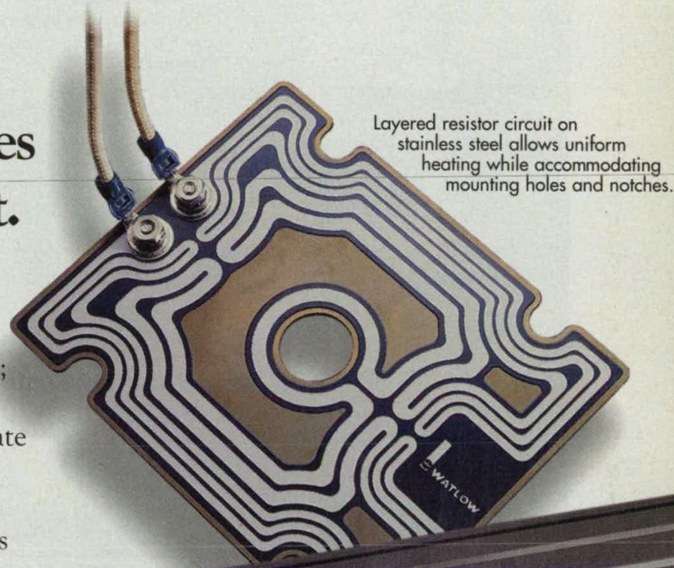
Federal Highway Administration **T9 Booth 517**
McLean, VA
The Federal Highway Administration (FHWA) will be displaying information on ways to improve our nation's roads. Learn why and how transportation in America is becoming intermodal.
Circle No. 677

Watlow Introduces A Better Way To Heat.

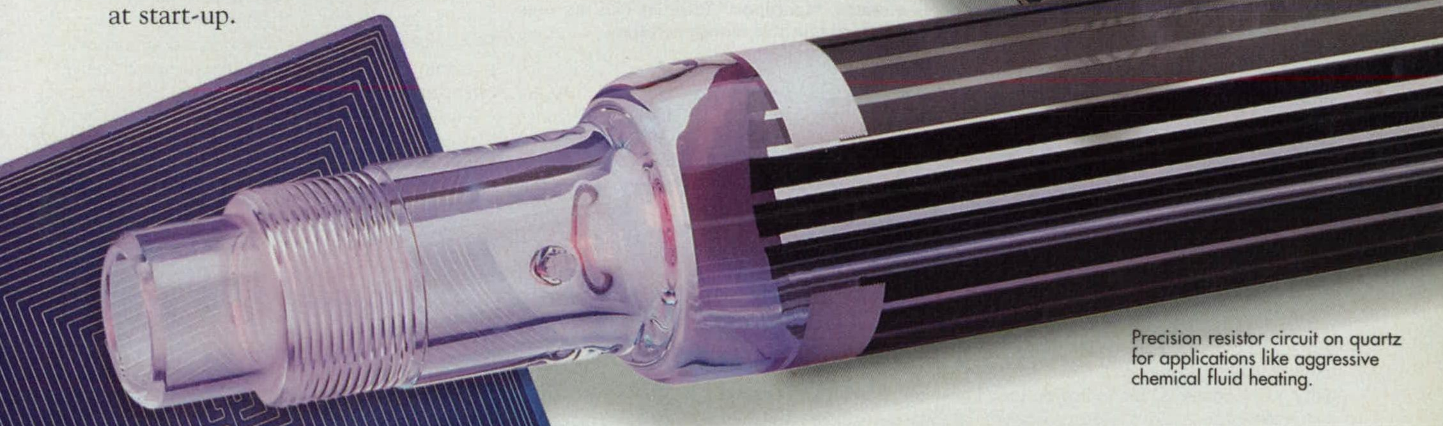
New Thick Film Technology Gives You The Kind Of Heat You Want.

Now you can achieve greater control of your heating applications with this breakthrough technology from Watlow. You get temperature capabilities to 500°C; temperature uniformity of ±2°C over the heated surface; fast response with low thermal mass, and greater heat transfer efficiency and heat-up due to thick film's intimate surface contact.

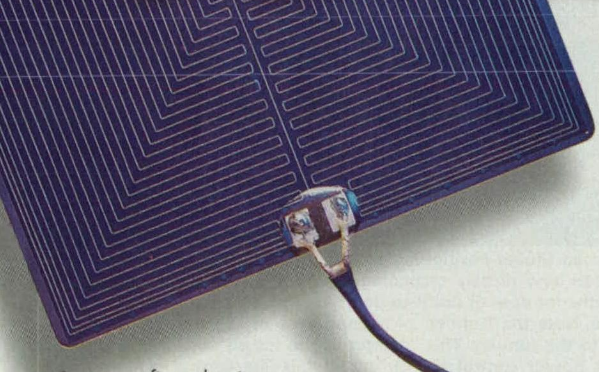
Tests in a specific application confirm increased yields of 30% and a reduction of 1.5 hours of production losses at start-up.



Layered resistor circuit on stainless steel allows uniform heating while accommodating mounting holes and notches.



Precision resistor circuit on quartz for applications like aggressive chemical fluid heating.



Custom-configured resistor circuit on 96% purity black alumina. This process allows ramping rates of up to 150°C per second while maintaining a uniform temperature.

Exactly Where You Want It.

The low profile of thick film heating technology lets you put the watts precisely where they're needed. You can apply heat directly to a variety of shapes and substrates – including 300 and 400 series stainless steel, quartz and ceramic – customizing your application to fit previously inaccessible areas or corrosive environments.

To find out how Watlow's new thick film technology can work for your application, access our web site or contact us at 1-800-4WATLOW (800-492-8569).

WATLOW

www.watlow.com/thickfilm

For More Information Circle No. 523

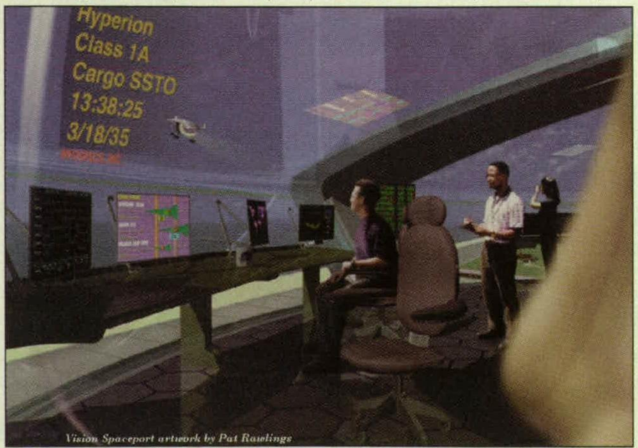
Technology 2009 will feature cutting-edge technologies being developed at NASA field centers around the country. Learn more about the following innovations at the NASA pavilion in the exhibit hall.

When routine, commercial spaceflight becomes a reality, "spaceport" facilities like the one shown here will be required to accommodate a variety of reusable launch vehicles.

Spaceports: Foundation for an Emerging Industry

NASA Kennedy Space Center's exhibit will focus on capabilities and technologies that will enable revolutionary "spaceports" of the future. During the NASA Business Forum, which is also part of Technology 2009, the Spaceport Synergy Team will present two panels bringing together technology and operations leaders in the rapidly emerging field of spaceport development. Representatives from the space industry will compare and contrast the requirements of spaceport users with the actual concepts and plans of new commercial spaceport facilities. Panel invitees include Beal Aerospace Technologies, the Boeing Company, Kelly Space & Technologies Inc., Lockheed Martin-VentureStar; Kistler Aerospace Corp., Rotary Rocket Co., Sea Launch, Space Access, Alaska Aerospace Development Corp., Spaceport Florida Authority, Spaceport Systems International, and Virginia Space Flight Center.

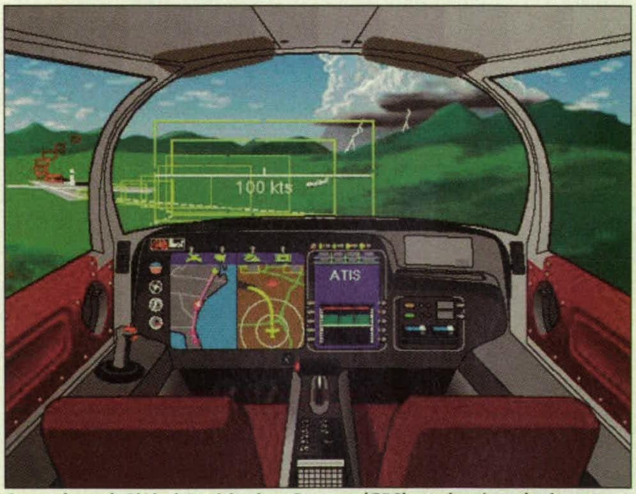
During the first panel — Spaceports for Future Spaceliners — potential spaceport users will discuss anticipated requirements for range services, airspace management, and payload-processing facilities, telecommunications, and other spaceport infrastructure. Leading spaceport visionaries will then respond with their concepts of how those needs can be met, with an emphasis on routine flight operations, lower costs, and safety. For the second panel — Spaceport Technology Visions — spaceport developers/operators will discuss challenges faced by the spaceport industry, new technology concepts, and upgrading existing facilities. Invited papers presented during this forum will address new concepts that offer the potential to revolutionize today's idea of a launch site and may point the way to technically and financially viable spaceports.



Spaceport operations might rely on an airport-style control tower, rather than using the traditional bunker-like "mission control" setup.

Highway in the Sky

NASA will feature two cockpit simulators allowing Technology 2009 attendees to take virtual test flights to compare current and next-generation technologies. The first simulator will replicate the general-aviation cockpit of today, made as pilot-friendly as possible with ergonomically designed, FAA-approved controls. The second simulator — presented by Embry-Riddle Aeronautical University and NASA's Advanced General Aviation Transport Experiment (AGATE) Alliance — will showcase the "cockpit of the future" in which antiquated dials and gauges will be replaced by large digital displays. These displays, developed under NASA's Highway in the Sky (HITS) program, are designed to give pilots an intuitive awareness of what's outside the plane. Borrowing from video-game technology, the HITS display keeps the pilot on course by providing a graphical tunnel of rectangles to follow, or "fly through."



Space-based Global Positioning System (GPS) navigation devices combined with new display technologies will depict intended and actual flight paths for ease of point-to-point navigation and precision landing guidance. Note the "tunnel" of rectangles — or Highway in the Sky — leading to the runway. This "cockpit of the future" also includes a single-lever power control (SLPC), automobile-like control switches and dials, as well as a moving-map navigation display.

AGATE is a joint NASA-FAA program designed to make single-engine, single-pilot planes as safe and economical as automobiles for trips

The moving-map display in the center of this AGATE cockpit console shows the aircraft's position and other flight information. Other features include the Integrated Cockpit Information System (ICIS), which provides the pilot with easily learned and operated systems.

ranging from 200 to 1,000 miles. Affordable glass-cockpit technology will provide pilots with direct access to the data needed to safely determine routes, speeds, weather conditions, and the proximity of other aircraft. NASA and the FAA intend for the design produced under the HITS program to define the standard for future general-aviation aircraft instrument panels.

In February 1999, the AGATE Alliance awarded its Highway in the Sky (HITS) contract to a team led by Avidyne Corp., Lexington, MA, and AvroTec, Portland, OR. The two companies and their partners will design the next-generation cockpit, which is expected to be completed in 2001.

Avidyne is designing the HITS software, which will generate digital displays using an "open systems" architecture that will integrate the best of today's advanced instrumentation; it can also be upgraded to incorporate future technologies. AvroTec will develop high-performance computing and display hardware — building from the company's FlightMonitor line of multi-function displays — to meet the demands of the highly graphical, intuitive HITS system.

Other technologies being developed under AGATE include the Integrated Cockpit Information System (ICIS), which provides the pilot with easily learned and operated systems and the Single-Lever Power Control (SLPC), a digital engine-control system. ICIS combines lessons learned through training psychology with advanced display technology to facilitate pilot training. SLPC will replace current three-lever power control systems with a single control much like an automobile's accelerator.

Federal Laboratory Consortium — **T9 Booth 525**
Cherry Hill, NJ
The FLC will feature a variety of federal technologies available for licensing and will also highlight various FLC services, such as the Laboratory Locator and Newslink newsletter.
Circle No. 676

Firexx Corporation — **IEP Table T43**
Arlington, VA
Circle No. 675

Florida Technological Research & Development Authority — **T9 Booth 424**
Titusville, FL
Circle No. 674

Florida Venture Forum — **SBTE Booth 228**
Coral Gables, FL
Circle No. 770

Gemfire Corporation — **T9SBIR Table T1**
Palo Alto, CA
Gemfire is pioneering very highly integrated photonics for display applications. Among the items exhibited will be a switch array with >1000 active devices per square centimeter.
Circle No. 673

Genex Technologies — **SBTE Booth 225**
Kensington, MD
Products to be exhibited include: a 3D camera/digitizer for acquiring 2D/3D models of complex objects; a volumetric 3D display system showing 3D images floating in space; and the OmniEye camera, which captures 360° images without using any moving parts.
Circle No. 672

GIDEP — **T9 Booth 423**
Corona, CA
GIDEP offers a technical documentation distribution system with information on discontinued or non-conforming parts or processes. Documents on engineering design, reliability, and test measurement will be available.
Circle No. 671

Global Solar Energy, LLC — **T9SBIR Table T13**
Wheat Ridge, CO
Circle No. 612

Goodfellow Corporation — **T9Lit Booth L1**
Berwyn, PA
Goodfellow offers more than 48,000 items in small quantities, available for shipment worldwide. Products include pure metals, alloys, polymers, ceramics, and composites.
Circle No. 670

Inframetrics — **T9 Booth 419**
North Billerica, MA
The company designs and manufactures infrared cameras, and offers predictive maintenance, non-destructive testing, surveillance, and temperature measurement.
Circle No. 668

Irvine Sensors Corporation — **SBTE Booth 224**
Costa Mesa, CA
ISC will exhibit CMOS visible imagers with IR data links; a variety of IR imaging systems; small silicon stacked electronic modules, and custom integrated circuits for advanced computing applications.
Circle No. 667

k Technology Corporation — **SBTE Booth 215**
Fort Washington, PA
Circle No. 666

Kigre — **SBTE Booth 221**
Hilton Head, SC
Kigre manufactures pulsed Nd:YAG laser systems, including the 1732 system called the "Workhorse."
Circle No. 665

Laptop Support System — **IEP Table T48**
Oregon City, OR
Circle No. 664

Launchspace Publications — **T9 Booth 626**
McLean, VA
Launchspace is the magazine of the space industry, reaching 80,000 professionals. Each issue focuses on significant industry programs and is free to qualified professionals.
Circle No. 663

Lawrence Berkeley National Laboratory — **T9 Booth 522**
Berkley, CA
Lawrence Berkeley Lab is a major national laboratory with more than 3,000 employees and an annual budget of more than $300 million. The lab has expertise in energy, environment, materials, computing, and biotechnology.
Circle No. 662

Lithium Power Technologies — **T9SBIR Table T3**
Missouri City, TX
Circle No. 661

Los Gatos Research — **T9SBIR Table T16**
Mountain View, CA
The Broadband Ringdown Spectral Photography (B-RSP) method developd by Los Gatos Research is a spectroscopic technique capable of acquiring ultra-high-sensitivity absorption spectra at high resolution over a large optical bandwidth, using broadband light sources.
Circle No. 762

Luna Innovations — **T9SBIR Table T17**
Blacksburg, VA
Circle No. 684

Mack Information Systems — **IEP Table T45**
Wyncote, PA
Circle No. 660

TECH EAST '99

Micro Surface Corporation — **IEP Booth 107**
Morris, IL
Circle No. 659

NASA Headquarters — **T9 Booth 509**
Huntsville, AL
Circle No. 658

NASA Headquarters — **SBTE Booth 500**
Huntsville, AL
NASA's display is scheduled to include the AGATE general-aviation cockpit simulator, information on reusable launch vehicles, and microgravity pharmaceutical research.
Circle No. 657

NASA Kennedy Space Center — **T9 Booth 409**
Kennedy Space Center, FL
KSC's exhibit will focus on the rapidly emerging field of spaceport development and related technologies for range services, airspace management, payload-processing facilities, telecommunications, and other spaceport infrastructure.
Circle No. 655

NASA Small Business Solutions Center — **T9 Booth 201**
Washington, DC
Displays will include NASA's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) program opportunities, NASA technologies developed through the programs, and a guide to other small business resources.
Circle No. 656

National Security Agency Technology Transfer — **T9 Booth 524**
Pacadena, MD
The National Security Agency has established a formal technology transfer mechanism for openly sharing reasonable technologies with industrial partners and academia.
Circle No. 654

Naval Surface Warfare Center — Crane Division — **T9 Booth 426**
Crane, IN
Circle No. 653

Niagara Industries — **IEP Table T41**
Miami, FL
Circle No. 614

Nitres — **T9SBIR Table T8**
Goleta, CA
Nitres Inc. (formerly Witech, LLC) will display high-power, high-efficiency, robust microwave and millimeter wave amplifier technology with Gallium Nitride (GaN). Markets include cellular base stations; L, S, X band radars; ku band satcom; LMDS; and GaN blue, green, and white emitters for lighting, illuminations, and display applications.
Circle No. 652

North American Technology & Industrial Base Organization — **SBTE Booth 208**
Alexandria, VA
Circle No. 651

Novespace — **T9 Booth 415**
Paris, France
The exhibit will describe European technology transfer networks established around *Novespace*, and will feature various technology catalogs.
Circle No. 771

Nu-Cast — **SBTE Booth 206**
Londonderry, NH
NuCast produces high-strength aluminum investment castings derived from computer-generated prototype patterns. Working with NASA engineering and technology, the company utilizes stereolithography (STL), selective laser sintering (SLS), laminated object manufacturing (LOM), computer-generated wood, and fused deposition modeling (FDM) technologies.
Circle No. 772

NZ Applied Technologies Corp. — **T9SBIR Table T15**
Woburn, MA
The company develops and manufactures fiber optic components for telecommunication applications. The Eclipse™ series of variable optical attenuators enable all solid-state, high-speed performance in a compact package.
Circle No. 615

Oak Ridge National Laboratory Hybrid Lighting **T9 Booth 518**
Oak Ridge, TN
Hybrid lighting combines natural and artificial light sources with advanced light distribution systems. These lighting systems offer improved light quality and efficiency.
Circle No. 773

Ocean Optics **T9Lit Booth L2**
Dunedin, FL
The company offers miniature fiber optic spectrometers for the UV, VIS, and Shortwave NIR. The units are custom-built to user specifications, and connect to a line of fiber optic accessories, including light sources, probes, and chemical sensors. Systems can be configured for a variety of optical-sensing applications.
Circle No. 774

Pacific Bearing Co. **SEDME Booth 319**
Rockford, IL
Pacific Bearing Co. is the manufacturer of the Simplicity self-lubricating linear bearings; Dolphin Guides™, a revolutionary new two-piece slide; Redi-rail™ linear guides; and Hevi-rail™ heavy-duty bearings.
Circle No. 775

Panasonic Factory Automation **T9Lit Booth L2**
Franklin Park, IL
Circle No. 776

Physical Optics Corporation, Engineering & Product Div. **T9SBIR Table T2**
Torrance, CA
Physical Optics offers video/audio/data, network, data, and multimedia products, which include unidirectional and bi-directional systems, video and multimedia extender systems, digitized audio/video/data, modems, and Ethernet transceivers.
Circle No. 777

Pure Water **IEP Booth 111**
Oakland Park, FL
Circle No. 613

Quantum Magnetics **SBTE Booth 209**
San Diego, CA
Circle No. 778

Radiant Research **T9SBIR Table T9**
Austin, TX
The company will exhibit 32-channel DWDM/DWDDM modules for single-mode and optical fiber transmission systems, along with special optical fiber coupling cables for efficient optical coupling between single-mode and multimode fibers.
Circle No. 779

Reveo **SBTE Booth 224**
Hawthorne, NY
Reveo is a technical problem-solving service providing advanced solutions in areas such as: frontier research in fundamental problems; technology development, prototyping, and consulting; and intellectual property licensing.
Circle No. 780

Rhode Flux **SEDME Booth 314**
Providence, RI
Rhode Flux is a technical solution provider whose stated goal is "to be the first to achieve a functional prototype." The company offers capabilities for taking engineering challenges from concept to completion, completely in-house.
Circle No. 781

Scientific Research Corporation **T9SBIR Table T6**
Atlanta, GA
SRC provides wireless connectivity to networks, using real-time adaptive error correction and quality-of-service and time-critical protocols to double the bandwidth or range and increase revenues.
Circle No. 782

Sensortex **SBTE Booth 219**
Kennett Sq., PA
Sensortex manufactures Multishield™, a multilayered composite that shields against magnetic fields. Applications include military and commercial avionics, architectural shielding, and signal and power-cable shielding.
Circle No. 783

Sentar **SBTE Booth 217**
Huntsville, AL
KnoWeb™ provides answers to questions and solutions to problems using the Internet or a corporate intranet.
Circle No. 784

Small Parts Inc. **SEDME Booth 321**
Miami Lakes, FL
Parts, components, metal and plastic materials, instruments, tools, and other items related to product development and fabrication are offered by Small Parts. Manufacturing services also are available for small-quantity prototype development or limited production runs.
Circle No. 785

SolidWorks Corporation **SEDME Booth 309**
Concord, MA
SolidWorks 99 is the seventh major release of the company's 3D mechanical design software. The new release contains more than 150 major customer-driven enhancements and innovations in the areas of modeling, assembly design, detailing, visual communication, data sharing, piping, and sheet metal. The software, originally released in 1995, was designed as the first Windows-native 3D design system for mainstream engineers.
Circle No. 786

Space Awareness Alliance **T9 Booth 516**
Tampa, FL
Circle No. 787

Sugatsune America **T9Lit Booth L2**
Carson, CA
Sugatsune supplies hardware for the machinery, marine, and construction industries. They offer more than 20,000 items, including fittings, casters, and hinges.
Circle No. 788

The Technology Exchange **T9 Booth 628**
Bedfordshire, England
The Technology Exchange is a non-profit organization dedicated to helping businesses exploit technologies/capabilities more profitably through exchanging profiles and promoting contacts.
Circle No. 789

Thermacore **T9SBIR Table T7**
Lancaster, PA
Thermacore manufactures heat pipes and other thermal management products for notebook and desktop computers, power modules, heat exchangers, telecommunications, mold cooling, and isothermal furnace lines.
Circle No. 790

Tiodize Co. **T9 Booth 408**
Huntington Beach, CA
The company offers composite fasteners, composite self-lubricating bearings, solid film lubricants, corrosion coatings, degreasers, and various special coatings.
Circle No. 791

TRI/Austin **T9 Booth 421**
Austin, TX
The company's specialties include composites, adhesives, coatings, foams, and polymer systems. Services include research, development, and testing experts in the field of material science; accelerated light testing; and nondestructive testing.
Circle No. 792

Triton Systems **T9SBIR Table T4**
Chelmsford, MA
Circle No. 793

Unigraphics Solutions **SEDME Booth 308**
Huntsville, AL
Unigraphics Solutions provides a combination of software products, and implementation and integration services, for enterprise-level MCAD users. The product suite includes Unigraphics, a high-end MCAD software for complex design projects, and Solid Edge, a Windows-based design and drafting software. Both are based on the company's core solid modeling kernel, Parasolid.
Circle No. 794

United States Marine Corps **T9 Booth 428**
Stafford, VA
Circle No. 795

If You Design Military/ Aerospace Motion Systems, Turn To Litton.

Military Qualified Motors

- Brush, brushless
- Cube
- Torque
- Toroidally wound

Military Qualified Slip Rings

- Miniature capsules
- Space/Vacuum
- Twist-capsules
- Vehicular
- Helicopter
- Pedestal

Military Qualified Resolvers

- Single and multispeed pancake and housed

Our integrated motion assemblies can include motors, slip rings, gears, resolvers, servo amplifiers and other components as required.

Targeted Technology

Litton Poly-Scientific's line of rotary motion components encompasses a complete selection of brush and brushless DC motors (including cube, torque and toroidally wound), slip rings and unhoused and pancake resolvers. These components are optimized for military/aerospace use and can, of course, be supplied to you individually, or combined into a complete rotary motion system that we call an IMT - Integrated Motion Technology System. IMTs are electrically and mechanically aligned, fully tested and ready to integrate into our customer's system.

Innovative Solutions

As a Joint Services Provider to all branches of the military, we can put our decades of experience to work for you. We excel at developing custom designs meeting military requirements. We will efficiently coordinate your needs with our engineering resources to slash development time and pursue very aggressive design and manufacturing schedules.

Superior Results

Our approach provides competitively priced, compact systems with unparalleled performance. By allowing us to be your one source for rotary motion systems, we will help you maximize your resources and focus on your global mission.

Litton

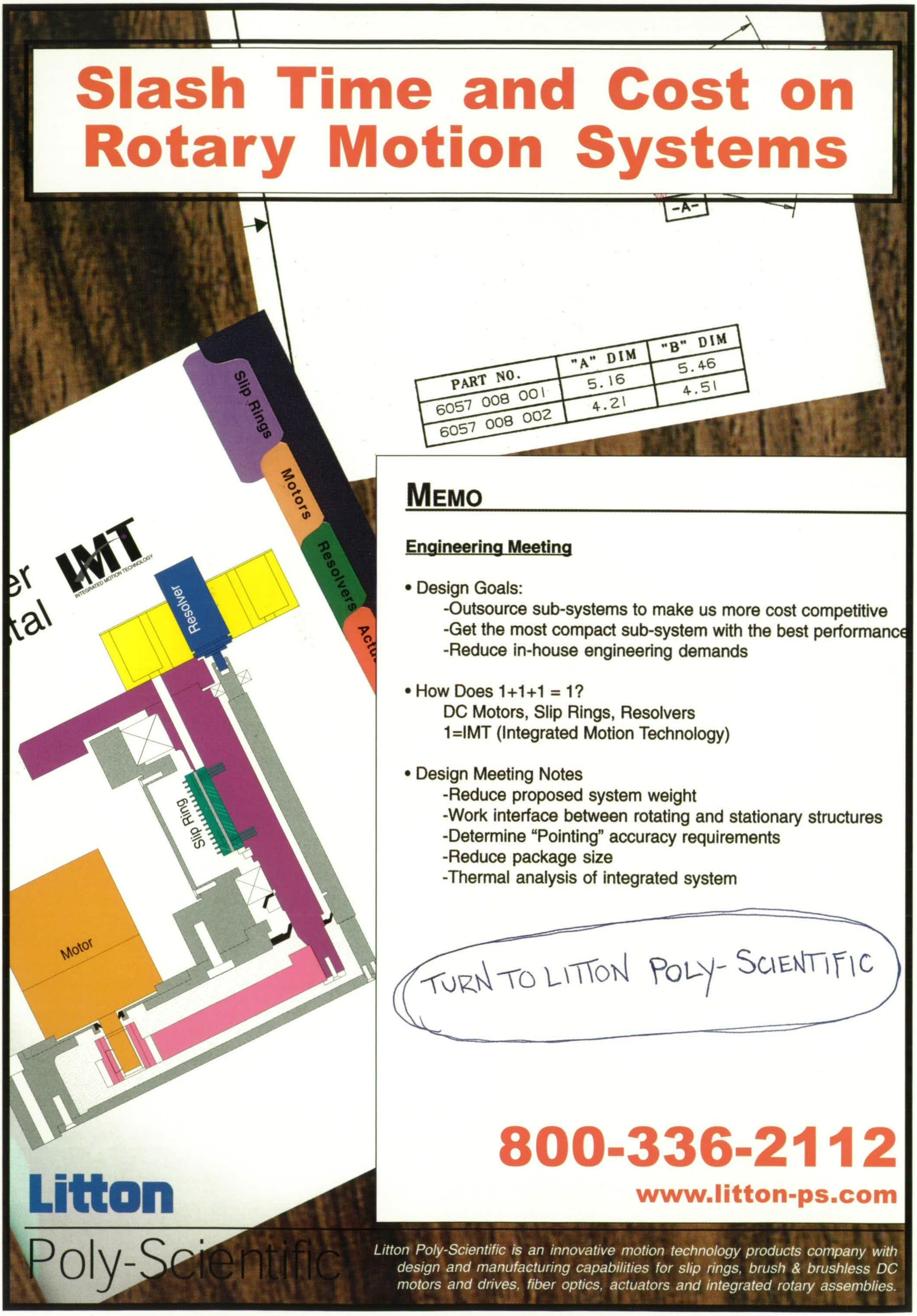
Poly-Scientific

800-336-2112, ext. 173 or 303

www.litton-ps.com

Litton Poly-Scientific is an innovative motion technology products company with design and manufacturing capabilities for slip rings, brush & brushless DC motors and drivers, fiber optics, actuators and integrated rotary assemblies.

For More Information Circle No. 408



For More Information Circle No. 408

US Air Force Research Laboratory — **T9 Booth 301**
Wright-Patterson AFB, OH

The US Air Force Research Lab is the Department of Defense's largest laboratory, which develops technologies for applications in human systems, information management, space, aircraft, and structures. Information on the lab's technology transfer program will be available.

Circle No. 796

U.S. Army Developmental Test Command (DTC) — **T9 Booth 325**
Aberdeen Proving Ground, MD

The Army's developmental tester for weapons and equipment, DTC tests military hardware of every description under precise conditions across the full spectrum of arctic, tropical, desert, and other natural and controlled environments. Tests are performed in support of the Department of Defense, other U.S. government agencies, private industry, and foreign governments. DTC's Technology Transfer Program promotes the transfer of DTC-developed technology and the sharing of its unique test facilities with industry.

Circle No. 765

US Army Edgewood Chemical Biological Center — **T9 Booth 420**
APG, MD

Circle No. 797

US Dept. of Agriculture — Agricultural Research Service — **T9 Booth 514**
Beltsville, MD

The Service's Office of Technology Transfer offers a range of patented technologies available for license. Business opportunities also will be exhibited.

Circle No. 798

US Dept. of Commerce — National Institute of Standards & Technology — **T9 Booth 416**
Gaithersburg, MD

NIST works with industry to develop and apply technology, measurements, and standards through its Measurement and Standards Laboratories, Advanced Technology Program, Manufacturing Extension Partnership, and National Quality Program.

Circle No. 799

US Dept. of Defense Dual Use Science Technology (DUST) Program — **T9 Booth 417**
Falls Church, VA

This program leverages research funds for military technology development with commercial industry in order to reduce costs and increase performance of military systems.

Circle No. 683

VerticalNet — **T9Lit Booth L3**
Horsham, PA

Circle No. 800

ViaSpace Technologies — **SEDME Booth 316**
Altadena, CA

ViaSpace is a technology incubation and development company that was founded by a former NASA physicist to license NASA technologies. Among those technologies are an infrared sensor, a laser diode, digital cameras, and a microhygrometer, all from NASA's Jet Propulsion Lab (JPL).

Circle No. 619

West Virginia High Technology Consortium Foundation — **T9 Booth 529**
Fairmont, WV

The Foundation serves as a catalyst for economic diversification by partnering with government, business, and academia to invest in the education of a quality workforce; research technologies for competitive advantage; and stimulate the development of a high-technology infrastructure.

Circle No. 616

Zito Alted Tepra — **SBTE Booth T50**
Damascus, MD

Circle No. 618

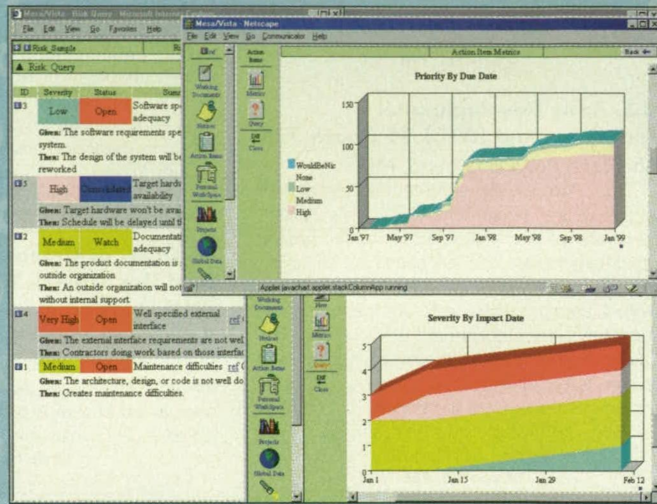
Zoeller Company — **IEP Table T47**
Louisville, KY

The three Louisville-based operations of the company are Zoeller Pump, which manufactures products for the plumbing industry; Zoeller Engineered Products, which makes submersible pumping products; and HiLo Industries, specializing in commercial-grade submersible and sewage pumps.

Circle No. 617

NASA Langley Streamlines Project Management

Mesa/Vista Risk Manager Web-based project management software
Mesa Systems Guild
Warwick, RI
401-828-8500
www.mesavista.com



The Office of Mission Assurance (OMA) at NASA's Langley Research Center in Hampton, VA, currently uses Microsoft Project and a specially designed Web-based document management system to manage multiple projects. The center is combining these tools with Mesa/Vista Risk Manager, a collaborative Web environment that provides the foundation to support a structured risk management process. The OMA is implementing the new software on multiple projects at Langley to provide risk management support and coordinate operations via the Web.

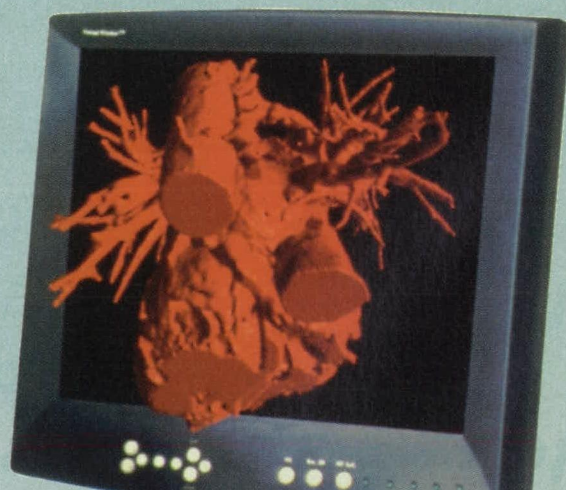
According to Jose Caraballo, lead assurance engineer at Langley, the center is now able to connect all of its project teams and corporate partners across the country through the new software. The use of the software is instrumental in providing project teams with the capability to develop risk management documents that meet Program and Project Management Processes and Requirements. Plans include allowing other NASA centers to access the system to provide similar support across the agency.

The Web-based technology provides all team members with relevant project information, and allows Langley to share partner companies' tools that are not on their current system, enabling cohesive collaboration.

For More Information Circle No. 735

NASA's Virtual Clinic Incorporates 3D Displays

DTI 2018XL 3D displays
Dimension Technologies
Rochester, NY
716-436-3530
www.dti3d.com



The Virtual Collaborative Clinic at NASA's Ames Research Center in California combines sophisticated medical imaging with high-speed, high-performance networking to allow doctors to receive and manipulate high-resolution, 24-bit, 3D color images in near-real-time. The technology enables collaboration and consultation over long distances for diagnosis and treatment. Using a "CyberScalpel," doctors also can "cut" into images and move "bone" around for surgical simulation using 3D images created from serial sections of tissues and organs generated by electron microscopy, MRI, and CT scans. The project is designed to enable patients in remote or medically underserved areas to be properly diagnosed and treated.

Part of the technology package used for this virtual clinic is the DTI 2018XL 18" 3D display that features a TFT LCD screen, display resolutions to 1280 x 1024 pixels, and 16.7 million colors. The viewing mode can be switched instantly from 2D to 3D, and selectable stereo viewing formats include side-by-side and field sequential. The display accepts S-video, standard NTSC, and PAL input signals.

Other participants in the clinic project include physicians at Stanford University, the Cleveland Clinic, the University of California at Santa Cruz, Salinas Valley Memorial Hospital (CA), and the Northern Navajo Medical Center in New Mexico. Commercial participants include Intel, SGI, Cisco Systems, Hughes, and MCI.

For More Information Circle No. 734

Commercialization Opportunities

Low-Power, Moderate-Speed Serial Communication Link

Designed originally to transmit data among subsystems of a spacecraft instrumentation system at rates of up to 5×10^5 bits per second, this link is adaptable to other applications, which include cellular telephones, laptop computers, and other compact, lightweight digital electronic consumer products.

(See page 43.)

GaN-Based Linear Array of Ultraviolet Detectors

This solar-blind array can operate at room temperature. There are numerous potential industrial, medical, and scientific research applications for these arrays.

(See page 50.)

Cheaper Polymeric Electrolyte Membranes for Fuel Cells

Developed for methanol fuel cells, these membranes are expected to cost from about one tenth to one twentieth the cost of conventional membranes. They also offer greater resistance to methanol crossover than do regular membranes.

(See page 56.)

Shrouds Would Catch Debris From Disintegrating Machines

Shrouds have been developed to protect people and equipment against high-speed debris ejected by the rotating machines. Such accidents can happen with gyroscopes and turbines.

(See page 58.)

Device Assists Actuation of a Joint in a Pressure Suit

This device has a number of potential applications beyond the space program. It could be used on inflatable mobility joints by individuals suffering from joint diseases and in therapy to restore movement to nonfunctioning limbs.

(See page 60.)

Modified Wire Tie

A conventional tie scored at short intervals along its length can be snapped off neatly without cutting and without leaving a sharp end.

(See page 62.)

Heated Weights for Adhesive Bonding

These weights provide both the heat needed to accelerate curing of the adhesive and the force needed to clamp the bonded parts. The risk of overheating is eliminated, without need for monitoring.

(See page 62.)

Whole-Blood-Staining Device

This device provides a means of staining white blood cells by use of monoclonal antibodies conjugated to various fluorochromes. The device is inexpensive and easy to produce.

(See page 64.)

High-Speed PC-Based Data Logging

Data loggers have evolved a great deal beyond paperbound strip chart recorders to the point where they are now used across many different applications in a variety of technical areas. From recording environmental test chamber conditions, to monitoring the stress on a truck axle, logging data for subsequent analysis is a pervasive requirement. When users are faced with high-speed data logging requirements, often they feel they must turn to proprietary systems to obtain a satisfactory solution. However, by building a high-speed data logging system around a personal computer, one can create a cost-effective, high-speed solution from off-the-shelf components. In addition to having user-defined features, the system also can be upgraded and modified in the future at a much lower cost.

Following are the key issues to consider when putting together a high-speed, PC-based logging system. From the choice of data acquisition (DAQ) and personal computer hardware, to driver and application programming software, there are a number of things one should factor in when building a system. The actual performance achieved with a particular high-speed data logging application also will be related.

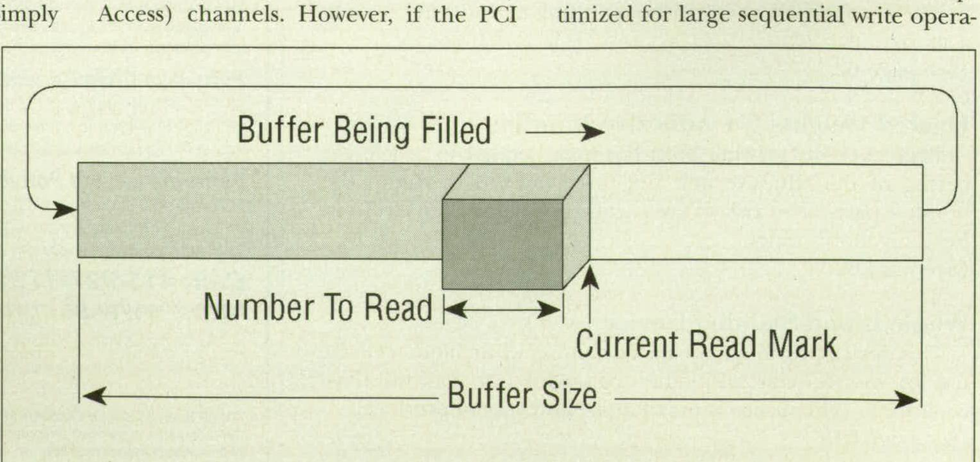
Links in the DAQ Chain

Anyone interested in logging data has a particular phenomenon they are interested in monitoring, so it is best to start at the sensor end of the system. Simply stated, transducers convert the signal of interest into voltages or currents, which are then conditioned — isolated, amplified, or filtered — until they are suitable to pass to a DAQ board. While users certainly need to utilize signal conditioning capable of the rates they require, signal conditioning is not usually the limiting factor in how rapidly data can be logged.

The next link in the data acquisition system is the analog to digital converter (ADC) or digitizer. The two principal factors to consider in choosing a digitizer are (1) the rate at which it samples, and (2) the method it uses to acquire those samples. Simultaneous sampling devices generally have one ADC per channel and convert a sample from each channel at the same time. Although this method is extremely fast, it is expensive to have multiple ADCs. Thus, it is common to use a multiplexer so that each of the channels is sampled in turn by a single ADC. With the multiplexing DAQ device, it is important to make sure that amplifiers and other onboard components adjust rapidly enough in switching between channels to produce an accurate representation of the input signals.

Once the DAQ device has acquired the data, it has to transfer that data back to the host computer. The speed with which it can do this largely is dependent on the bus the computer uses. Certainly, one of the principal reasons that PCI (along with the more robust, industrial standard PXI™/CompactPCI) is the preferred bus for computer-based DAQ is its high throughput — theoretical maximum rate of 132 Mb/second. Coupled with that high throughput is a feature called bus mastering, during which the PCI board takes control of the bus and moves data across it to memory at a high speed without processor interaction. Bus mastering provides a significant advantage over the older ISA bus in that the computer motherboard does not have a finite number of DMA (Direct Memory Access) channels. However, if the PCI board is not capable of acting as the bus master, throughput performance is reduced, possibly below that of ISA with DMA. While their specific mechanisms differ, CardBus (an improvement to the PC Card PCMCIA specification), VXI, and IEEE 1394 also are buses capable of high throughput. The parallel port interface (maximum rates of approximately 25 kSamples/second) is in general much too slow to be considered for high-speed data logging. And USB, while slightly faster at rates up to 100 kS/s, also can be too slow for some applications.

Once the data is streaming back across the bus from the DAQ device, it has to be logged or written to a hard drive. The two principal types of hard drives that are practical for most users from a cost standpoint are IDE and SCSI drives. IDE hard drives are the type included in nearly all personal computers. Their performance has increased noticeably, and while they might be suitable for some data logging applications, if one intends to log more than four to six Mb/s, they probably will have to go with a SCSI drive. Some computer motherboards come with built-in SCSI controllers; however, most computers will require a plug-in PCI interface card to connect to a SCSI hard drive. Based on the application, various SCSI hard drives store data at rates ranging anywhere from 5 Mb/s up to in excess of 25 Mb/s. The large storage rates are characteristic of A/V (audio/visual) drives that are optimized for large sequential write opera-

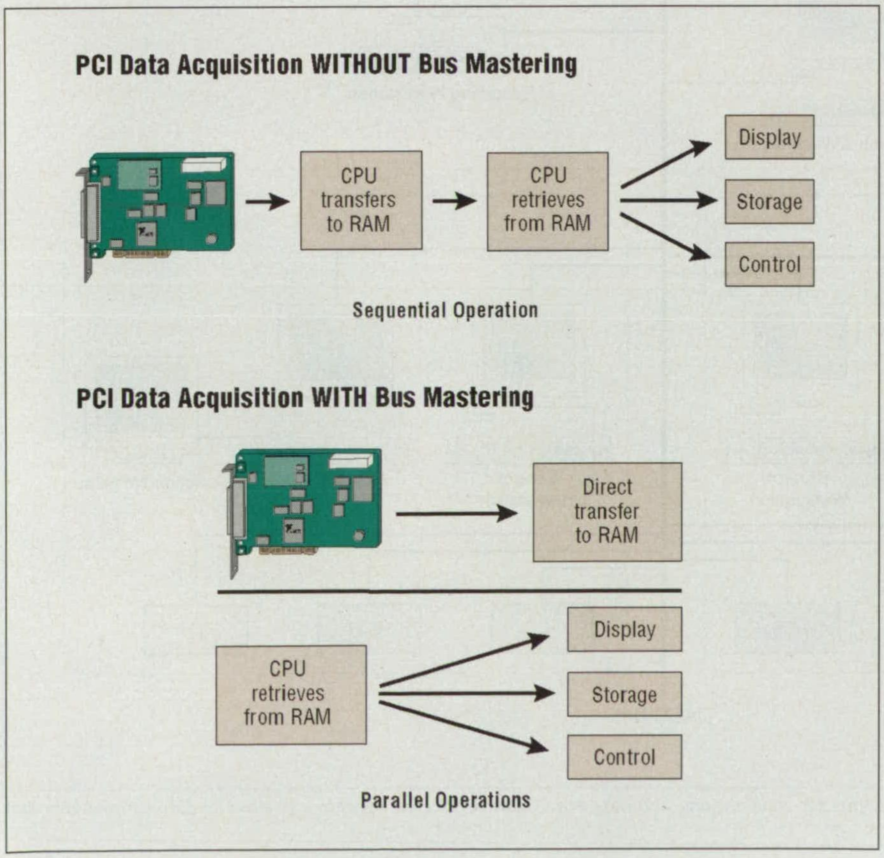


By building a high-speed data logging system around a PC, a cost-effective solution can be created from off-the-shelf components.

tions. The RPM at which the platters of the hard drive spin and the technique employed to actually write the data can be more important than the number of write heads. As a result, it is important to choose an A/V drive that is optimized for continuous rather than burst transfers, and to consider the overall performance of the drive rather than a single specification. If a single SCSI drive will not be able to log fast enough, it often is more economical to write to multiple SCSI drives in succession rather than moving up to an even higher performance type of hard drive.

Software Considerations

Driver software and application programming software also impact the overall throughput possible with the DAQ system. It is important that DAQ driver software does not impose limits on the throughput performance of the hardware, and provides access to the full functionality of the driver software. Of particular importance in today's user-interface-laden operating systems is the driver software's capability to bus master or use DMA and account for interrupt latencies. Perhaps the most important feature of DAQ driver software for data logging purposes is the ability to perform double buffering. In double, or circular buffering, data is written to a large block of memory, wrapping around to the beginning of the buffer and overwriting the older data each time the end of the block is reached. This process can continue indefinitely as long as the application and driver software are able to retrieve the "older" data before it is overwritten. Double buffering allows for logging of an unlimited amount of data — certainly more than could be held in computer memory at once. In addition to the ability of the driver to continuously acquire data, the formats in which data are stored also can be important. Typically, a floating point value such as 2.89 volts will be stored in 4 bytes in computer memory. If the driver software is able to pass binary values (the output of the ADC converter — usually 12 or 16 bits) directly back to an application, then those 2 bytes of data can be written to disk and 2 bytes per data value can be saved. Of course, one also would want to save the parameters that specify how to scale that binary data, but that can be done once at the beginning of the file and a dramatic reduction in storage space will still be seen.



In one specific high-speed data logging application, the system used for benchmarking consisted of a simultaneous-sampling, 4-channel PCI-6110E, PCI-based Dell Dimension XPS R350 machine running Windows NT 4.0 (FAT file system); an Adaptec SCSI/PCI controller; and LabVIEW™ software to log data to a Seagate Cheetah™ series SCSI hard drive. Using this system, 8 Msamples/s or 12 Mb/s were logged. To reduce the data rate and the amount of storage space required, a simple compression algorithm was employed to remove four unused bits from every sample — even though one sample from the 6110E board is only 12 bits, it is stored in computer memory as a 16-bit/2-byte number. In order to log to disk at the maximum rate that the board could acquire on four channels — 20 Msamples/s — successive blocks of data were written to three different SCSI drives in series.

There are a number of factors that affect the overall performance of a computer-based, high-speed data logging system. Being aware of hardware acquisition rates, bus throughput capabilities, hard drive storage rates, and software capabilities — as well as choosing system components that properly address those factors — are the keys to building a computer-based logging system that best meets specific needs.

For more information, contact the author of this article, Josh Martin, Application Engineer, at National Instruments, 6504 Bridge Point Parkway, Austin, TX 78730-5039; Tel: 512-683-0150; Fax: 512-683-5678; www.ni.com.

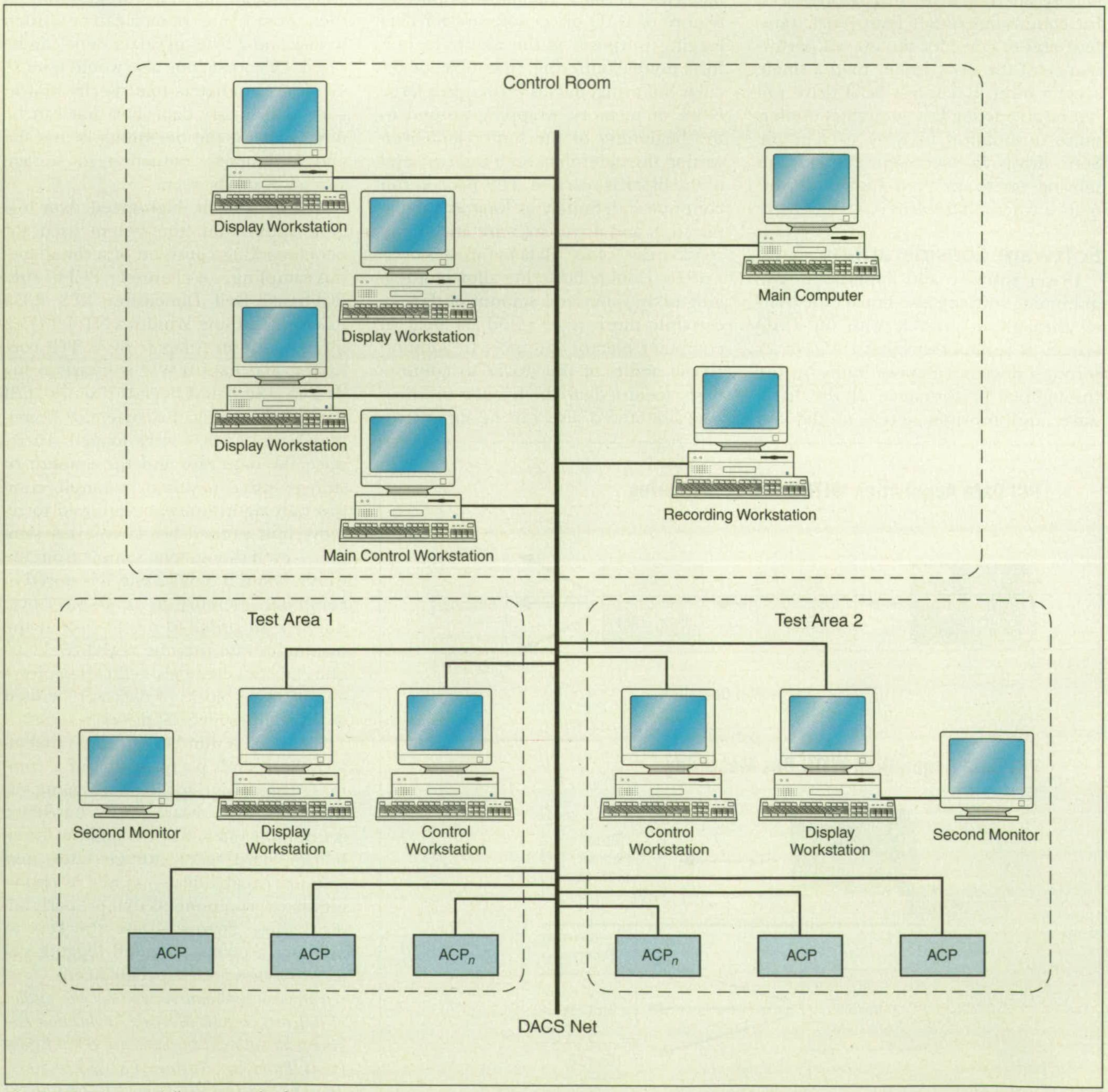
Special Coverage: Data Acquisition

Third-Generation Data-Acquisition System Now in Operation

Setup of test data bases, recording of data, display functions, and troubleshooting are simplified.

Dryden Flight Research Center, Edwards, California

Dryden Flight Research Center's Flight Loads Laboratory (FLL) was constructed in 1964 for use in performing combined mechanical and thermal tests of structural components and complete flight vehicles. The FLL is also used to calibrate and evaluate flight-loads instrumentation under the conditions expected in flight. The required testing is performed by the FLL's data-acquisition and control system (DACS).



The **DACS III** is essentially a network of computers, computer workstations, and data-acquisition circuits. This system contains standard components that can be easily replaced with newer versions.

A major portion of the FLL's third-generation data-acquisition and control system (DACS III) has been placed in service: This system is being developed in phases through the combined effort of a team composed of both civil-service and contractor personnel. The second-phase version of the system — now fully operational — performs data-acquisition, display, and replay functions, and provides troubleshooting tools. The DACS III provides enhanced capabilities that greatly increase productivity and efficiency.

The DACS III (see figure) consists mostly of a network of computers and workstations linked in a manner to provide maximum flexibility. This system has been designed to prevent obsolescence by use of industry-standard components that can be easily replaced when newer versions are introduced. An extensive use of graphical-user-interface (GUI) techniques simplifies test-setup definitions (test scenarios) as well as test operations and troubleshooting. A minimum time of two to three days was needed to generate a scenario for a typical test by use of the previous DACS. Operators can now generate the same test scenario in two to three hours by use of the DACS III.

The DACS III includes at least one acquisition-and-control processor (ACP) based on the VersaModule Eurocard (VME) and uses WindRiver's Vxworks real-time operating system. An installed Inter Range Instrumentation Group B (IRIG-B) interface card provides time stamping of sampled data. The data-acquisition system can be scaled up to 1,280 channels by using multiple ACPs, and operates at rates that vary from 10 to 160 samples per second.

This system has been designed to function in an environment that includes harsh electrical noise. All analog inputs are fed to the ACP(s) through fiber-optic cables to reduce electromagnetic interference. Each analog input module is an independent analog-to-digital (A/D) converter that generates 16-bit data by the sigma-delta conversion method. All A/D modules feature 1,500-volt isolation and 100 dB of normal-mode rejection at a frequency of 60 Hz.

Each ACP provides local recording of raw data and real-time conversion of engineering units. A key feature of the system is its ability to broadcast engineering-unit-converted data over an Ethernet. These data can be displayed throughout the laboratory on workstations that are equipped with the appropriate display software and attached to the DACS network.

The DACS III includes a data-display system that provides distributed real-time data displays updated at a rate of 5 samples per second. A user can choose several displays that can be overlaid on the same screen. All display parameter entries are driven by a GUI. The following types of displays are available: alphanumeric, x-y plots, vector, bar graph, force-stiffness, and derived parameter. All display engineering workstations are equipped with 21-in. (53-cm) monitors.

Control engineering workstations provide centralized control of test and recording processes for associated ACPs. Calibration functions, troubleshooting, event displays and record control are all available at these stations. The main control workstation performs the same functions as do the control engineering workstations, and offers the additional capability to control any or all of the ACPs.

A recording workstation is dedicated to recording the broadcast data from the ACPs. The recorded information is saved in a format that makes it available, immediately following a test, for evaluation by use of plotting software developed at Dryden Flight Research Center.

The DACS III includes a main computer (not to be confused with the main control computer) that is used for processing raw or engineering-unit-converted data logged during a test run. This computer also serves as the engine for all data-base functions.

One final feature worthy of note is a test-replay option, which enables research engineers to replay portions or all of a test run following a test. The replay can be at the original broadcast speed or slower. Full data-display functions are available during replay. There is also an option to generate displays during replay that were not used during the original test run; this option makes it possible to examine data of interest at a greater level of detail than what was available during the test run.

This work was done by Alphonzo J. Stewart, Allen Parker, Jr., Knut Roepel, and Van Tran of **Dryden Flight Research Center** *and Manuel Castro, Ronald Rough, and Chris Talley of the Woodside Summit Group. For further information, write to Alphonzo J. Stewart, NASA Dryden Flight Research Center, P. O. Box 273, Edwards CA 93523; call (805)258-3579; or send electronic mail to al.stewart@dfrc.nasa. gov*

DRC-99-10

Software for Managing Distributed Real-Time Data

Collaborative computing and acquisition of data are combined.

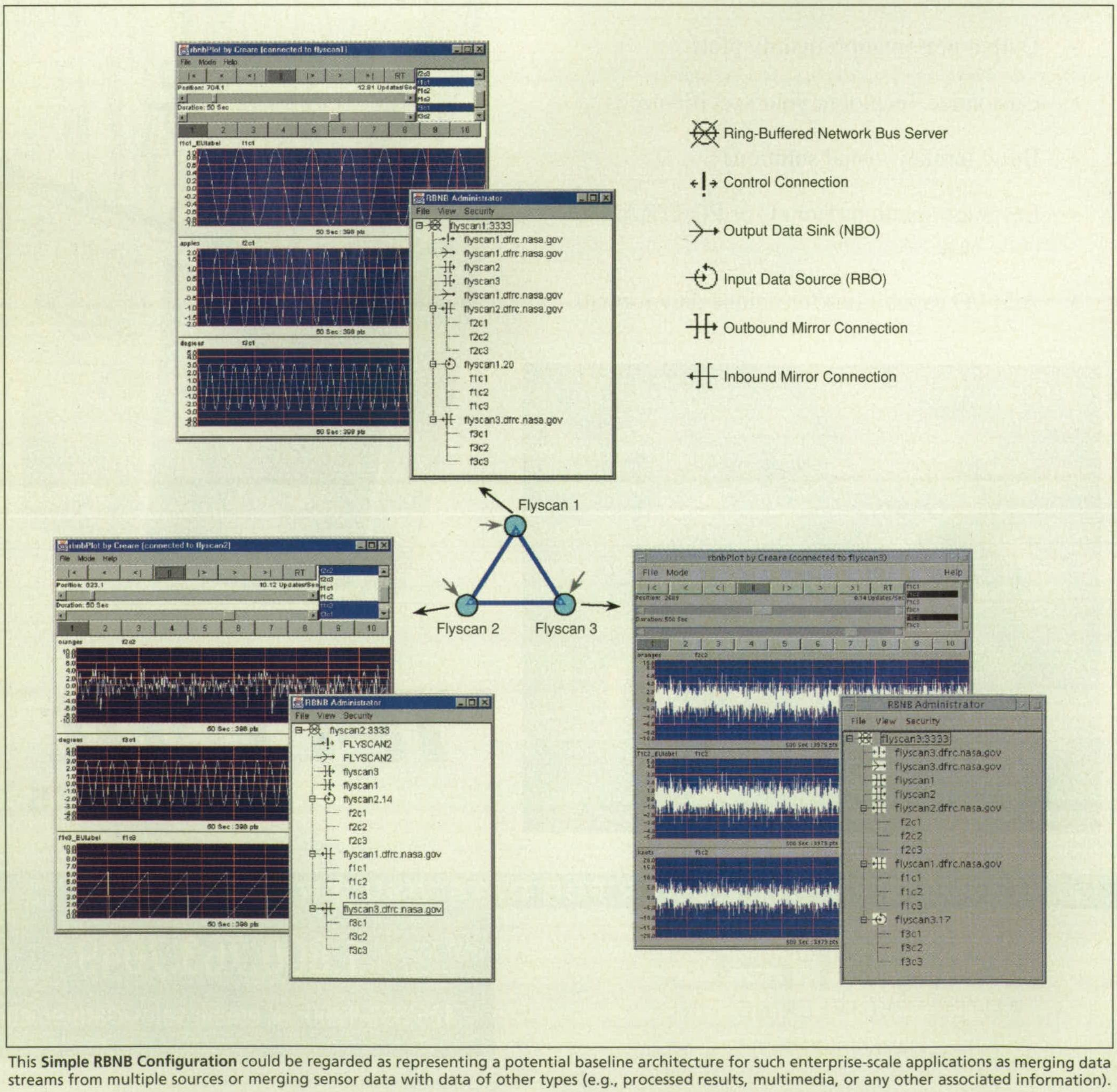
Dryden Flight Research Center, Edwards, California

An all-software data server has been invented to enable any set of connected application programs to create or gain access to live data streams. (As used here, "connected" signifies running on either the same computer or on different computers and communicating via the Internet, an intranet, or another network.) In combination with seamless archiving and retrieval of historical data, the invention offers new opportunities for distributed computing.

The Ring-Buffered Network Bus (RBNB™) is an all-Java-software data server that makes the network appear to be, simultaneously, a shared-memory server, a data-acquisition system, and a distributed data base. It extends the Transmission Control Protocol/Internet Protocol (TCP/IP) sockets subprotocol by incorporating a frame/channel management scheme and the ability to split and merge data streams on a channel-by-channel basis. Because streams can be routed or mirrored to other RBNB servers, configurations can readily be scaled for reasons of performance, redundancy, and security.

Core RBNB architectural components are software objects that manage streams (frames) of data. A frame is a time-stamped unit that contains one or more channels of data, each channel containing one or more data elements. Successive frames can contain fixed or variable sets of channels.

An essential part of the RBNB is a ring buffer object (RBO). For input of data from a particular source, an RBO acts as both a data server and an archive manager. An RBO manages multiple frames in a ring buffer that effects a seamless



This **Simple RBNB Configuration** could be regarded as representing a potential baseline architecture for such enterprise-scale applications as merging data streams from multiple sources or merging sensor data with data of other types (e.g., processed results, multimedia, or any other associated information).

transition from RAM to disk. The "ring" of an RBO is a circular buffer that, if necessary, writes over oldest data. Users can add descriptive header information to support a variety of downstream data-management and -processing schemes.

For output of data, a network bus object (NBO) manages requests for data and sends the selected channels. The output data stream is a new stream that contains frame and channel header information from one or more originating RBO sources. The user or the data sink can request individual frames and time slices, or can request that the data be streamed continuously for higher performance.

The core RBNB routes data as structured blocks of bytes; by design, the RBNB does not respond to or alter the intrinsic data format. This feature provides optimal flexibility and efficiency, but leaves the job of "understanding" data to the associated sources and sinks. When it is preferable to increase compatibility among otherwise incompatible sources and sinks, "plug-in" format converters can be invoked. A format converter (FC) processes the source data, creating the desired stream for the data sink. Examples of format conversion include simple units conversion, decompression, decryption, demultiplexing, or any other operation on the data. Channels of information created by FCs are indistinguishable from other channel types. Format conversions are independent processes that are executed locally or on remote computers.

The figure shows a simple RBNB configuration that involves three computers on a network (flyscan 1, flyscan 2, and flyscan 3). On each computer, an RBNB server accepts requests from data sources and data sinks. On each computer, a source process prepares three signals and sends them to an RBO in the local RBNB server. Mirrors are set up from each RBO to two remote RBNB servers, providing local access to all nine channels from any of the three servers. In the figure, a graphical view of connections is provided via a management utility called "rbnbAdmin." Access to the data is demonstrated on each computer via a strip-chart utility program, called "rbnbPlot," also running on each computer.

The performance of the all-Java data server is impressive. Aggregate throughput on modern personal computers and entry-level workstations exceeds 12MB/s to random-access memory (RAM) and 8 MB/s to disk. Performance continues to improve as computer technology and Java both mature.

This work was done by Lawrence C. Freudinger of **Dryden Flight Research Center** *and Matthew J. Miller, Ian A. Brown, and William R. Baschnagel of Creare, Inc. The Small Business Innovation Research (SBIR) contractor has elected to retain rights in the invention and a patent is pending. The contractor will introduce the RBNB in 1999 as a commercial product. Additional information is available on line at http://outlet.creare.com/rbnb. Inquiries should be addressed to the SBIR Technology Transfer Office, NASA Dryden Flight Research Center; telephone (805) 258 3720. DRC-96-34*

Low-Power, Moderate-Speed Serial Data Communication Link

Characteristics include low mass, low volume, low noise, and low power consumption.

Goddard Space Flight Center, Greenbelt, Maryland

A low-power serial data communication link has been designed to transmit data among subsystems of a spacecraft instrumentation system, at rates up to 5×10^5 bits per second. The design of the link is adaptable to other spacecraft systems and to terrestrial applications that include cellular telephones, laptop computers, and other compact, lightweight digital electronic consumer products.

The design had to satisfy requirements for low power consumption, small volume, small mass, and radiation hardness.

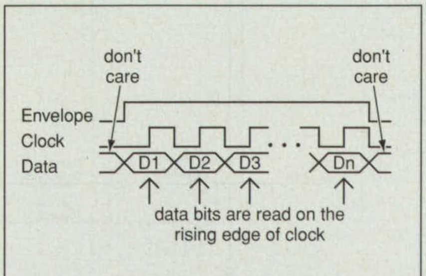


Figure 1. The **Data-Shifting Scheme** incorporates differential signals that include clock, data, and envelope signals.

Signals were required to be transmitted via differential networks to help minimize noise effects. The link was required to function over data-transmission lengths up to 1 m, and in the presence of potential differences of as much as 0.5 V between receiver and transmitter electrical grounds. In addition, there was a requirement that subsystems on the network that were powered down could not become powered up through the serial link.

The differential signals in the link include a clock signal, a data signal, and envelope signals (see Figure 1). An envelope signal becomes active at one-half period before the first rising edge of the clock signal and remains active until the end of the ensuing transfer of data. Data

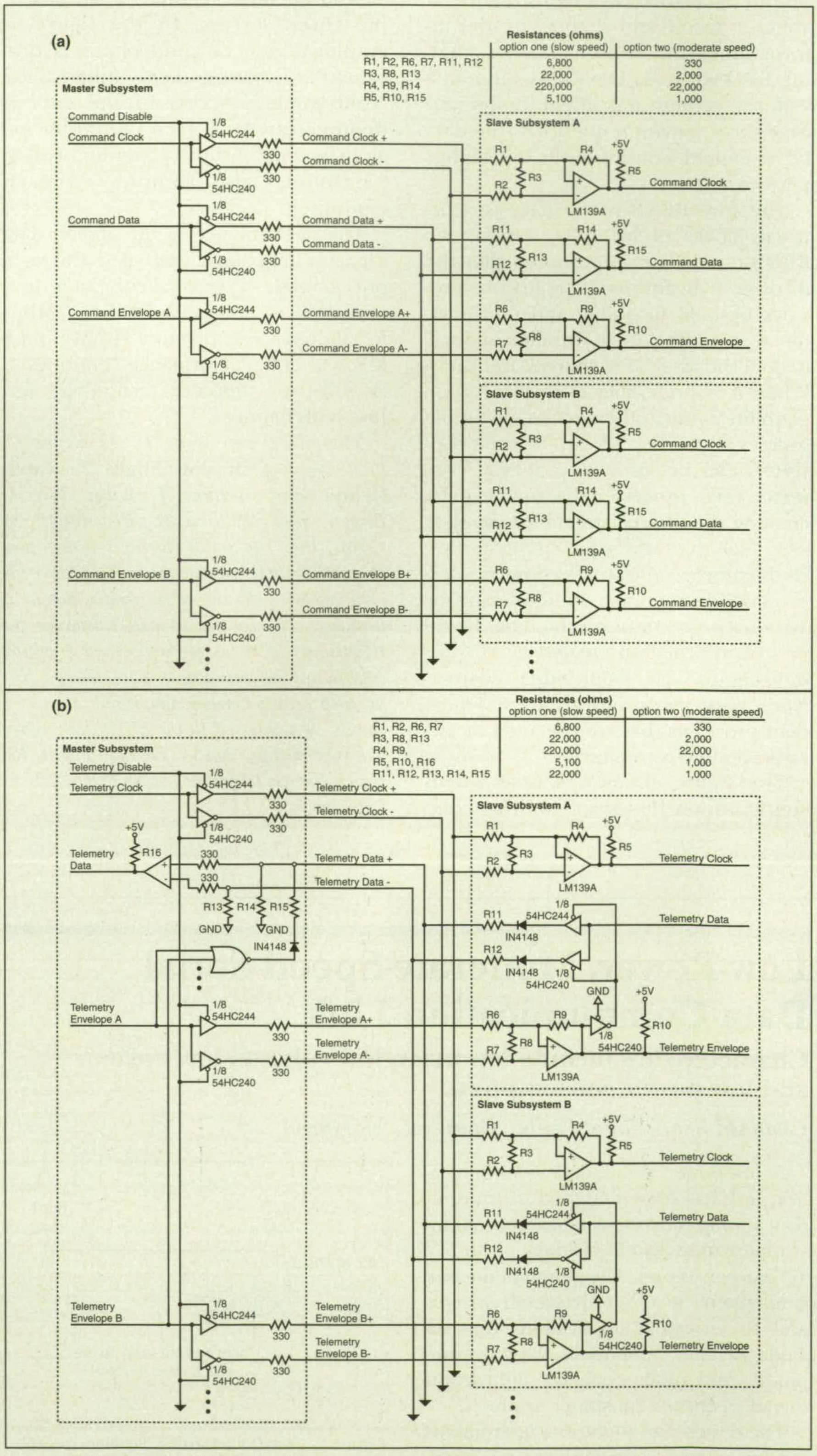


Figure 2. The **Serial Link includes** (a) transmitting differential network and (b) receiving differential network.

bits are valid on the rising edges of the clock signal.

The serial link includes a master subsystem that transmits commands to, and receives telemetric data from, numerous slave subsystems. Because there is a single source of commands and there are multiple sources of telemetric data, the serial link is divided into a command portion that includes a transmitting differential network [see Figure 2(a)] and a telemetry portion that includes a receiving differential network [see Figure 2(b)]. For each portion, there are two design options: one for data rates up to 2×10^4 bits per second, and one for data rates up to 5×10^5 bits per second. The higher-data-rate option involves smaller resistance values and thus higher power consumption. In both portions, all slave subsystems receive the same clock and data signal pairs, while each slave subsystem receives its own envelope signal pair. Each envelope signal pair indicates the subsystem to which the data are to be sent.

The serial link offers the following advantageous features in addition to those mentioned above:

- The circuitry includes LM139A comparators with feedback resistors connected to them to add hysteresis and thereby provide some immunity to noise. This feature is useful if the differential inputs to a comparator are differentially delayed because of differences in lengths of signal conductors.
- Voltage dividers connected to the comparator input terminals allow slave subsystems' ground potential to differ from the master subsystem's by as much as 1 V.
- All current loops carry small currents. The comparator input currents are smaller than 1 μA. The current flowing between any two subsystems is smaller than 5 mA. Interference and grounding problems associated with current loops are therefore less severe than they might otherwise be.
- Options are available by varying the basic design. Command and telemetry clock signals can be combined into a single clock-signal pair to reduce complexity. Similarly, the command and telemetry envelope signals for a subsystem can be combined into a singe signal pair. These changes lead to simultaneous transmission and reception. Other options include the use of part of the slave circuit design in the master in the event that only one source of telemetry data is used, modifications to enable the slave to be unpowered while the master is powered, and an alternative design that calls for LM119A comparators to increase the speed of the network beyond that achievable with LM139A comparators.

This work was done by Kenneth W. Wagner of **Goddard Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category. GSC-13926*

Data-Acquisition System Takes 8-Bit Samples at 1 GHz

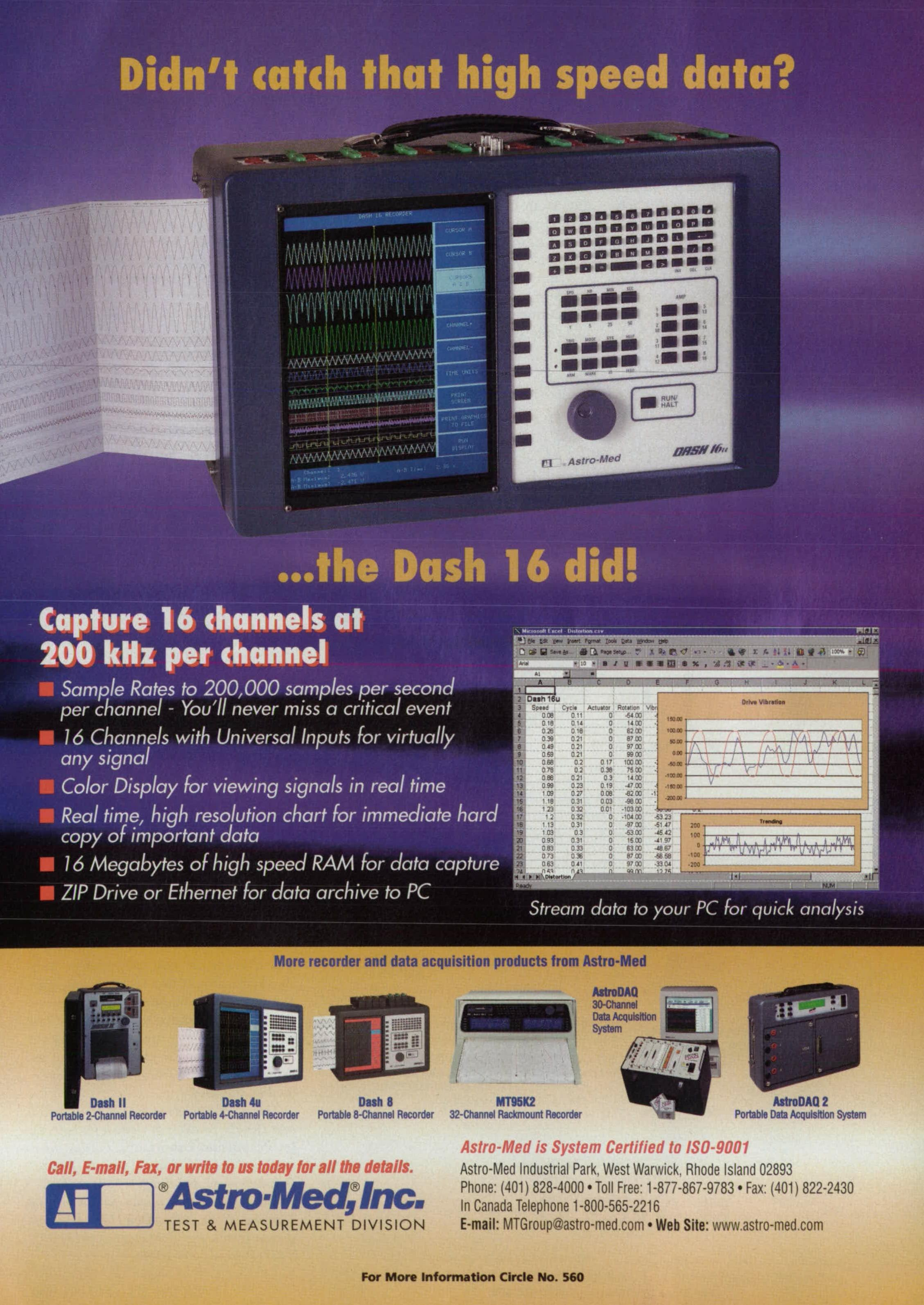
There are numerous potential applications in high-speed sampling and processing of signals.

Goddard Space Flight Center, Greenbelt, Maryland

A unique data-acquisition system converts analog input voltages to 8-bit digital data at a rate as high as 10^9 samples per second (1 GHz), stores the data, and makes the data available for further processing. The system is compact, is highly resistant to ionizing radiation, consumes relatively little power, and is made from commercially available components. Designed for original use as part of a spaceborne laser altimeter, such data-acquisition systems could be adapted to potential terrestrial use as general-purpose high-speed analog-to-digital converters in electronic test equipment and scientific instruments, and as memory devices for storing data to be processed in digital signal-processing systems.

The major subsystems and functions of the system are as follows: The system includes an 8-bit, 1-GHz analog-to-digital converter (ADC), emitter-coupled logic (ECL) circuits to slow (as explained below) the data signals to 83.33 megasamples per second, programmable gate arrays that further slow the data signals for efficient writing, and a static random-access memory (SRAM) that stores the data. If the data are encoded (as explained below) then in making the stored data available for processing, the programmable gate arrays are also reused as decoders during readout from the SRAM.

The master clock signal for the system is a sinusoidal signal with a fre-


Didn't catch that high speed data?
...the Dash 16 did!
Capture 16 channels at 200 kHz per channel
Sample Rates to 200,000 samples per second per channel - You'll never miss a critical event
16 Channels with Universal Inputs for virtually any signal
Color Display for viewing signals in real time
Real time, high resolution chart for immediate hard copy of important data
16 Megabytes of high speed RAM for data capture
ZIP Drive or Ethernet for data archive to PC
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More recorder and data acquisition products from Astro-Med
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Portable 4-Channel Recorder
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For More Information Circle No. 560

quency of 2 GHz. This signal is processed through a 2:1 frequency divider to obtain a 1-GHz, 1/2-duty-cycle square wave, which serves as a timing signal for the ADC. In the ADC, the input signal that one seeks to process is digitized to 8 bits. The ADC internally demultiplexes the digital data signal into two 500-MHz ECL channels, each channel containing the 8 data bits plus a data-ready signal. ECL flip-flops and shift registers then slow the 500-MHz data signals from the two channels into 83 1/3-MHz signals in twelve channels.

The data signals in the twelve 83 1/3-MHz channels are converted from ECL to transistor/transistor logic (TTL) levels, then passed to programmable gate arrays. The gate arrays contain flip-flops that collect the data in groups of four bytes. The gate arrays also contain logic circuits that generate standard address, chip-selection, reading, and writing signals for storing the data in or reading data from the SRAM at a rate of 20.833 MHz. In addition, the gate arrays generate a signal that indicates when the SRAM is full.

Acquisition of data is enabled or disabled by a single digital input bit. When acquisition is not enabled, the gate arrays collectively serve as a portal through which a digital processor can read data from, and write data to, the SRAM by use of the processor's own address, chip-selection, reading, and writing signals. The data can be Gray-coded or Gray-decoded during such reading or writing. The data path between this system and a digital processor is 32 bits wide; this feature makes it possible for a high-performance processor to gain access to four data samples per transaction.

This work was done by Kenneth W. Wagner of **Goddard Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
GSC-14176

On-Line System Provides Accurate Ephemeris and Related Data

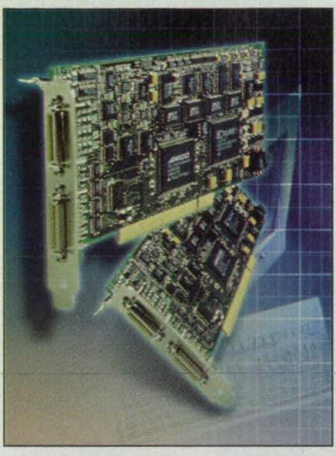
NASA's Jet Propulsion Laboratory, Pasadena, California

The Horizons On-Line Ephemeris and Data System ("Horizons" for short) is a computer program that provides data on the locations, motions, and dynamical parameters of solar-system objects, including the Sun, nine planets, 61 natural satellites, more than 16,000 comets and asteroids, and several dynamical points. Designed to be the reference standard for solar-system dynamical astronomy, Horizons is more comprehensive than any ephemeris or almanac published before in paper or software, and its data are the most accurate available from any source. Designed for use by professionals, Horizons can also be used by others; it is maintained on a server computer and is accessible to the public via the Internet. A user is given the best information available at the time of use. Horizons operates in multiple coordinate systems, includes a many-body integrator that propagates asteroid and comet orbits, and provides a search capability for identification of astronomical objects from parameters specified by the user.

This work was done by Jon D. Giorgini and Donald Yeomans of Caltech for **NASA's Jet Propulsion Laboratory.** *Further information should be requested via the Internet from http://ssd.jpl.nasa.gov/horizons.html.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20416.

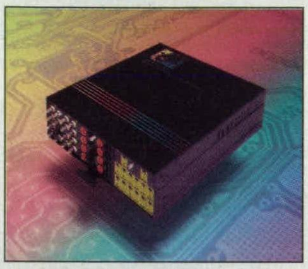
Special Coverage: Data Acquisition



Keithley Instruments, Cleveland, OH, has introduced the KPCI-3107 and KPCI-3108 wide-gain, high-resolution **data acquisition boards** for PCI-bus-equipped PCs. Providing gains of 1, 2, 4, 8, 10, 20, 40, 80, 100, 200, 400, and 800, the boards also feature an onboard FIFO buffer to enable continuous acquisition of large amounts of data, and an analog input speed of 100 Ks/s.

The boards offer 16 single-ended or 8 differential inputs with 16-bit resolution. Both models have 32 digital input and output channels, sinking 64mA and sourcing 15mA. The Model 3108 has two waveform-quality 16-bit analog outputs with speeds to 100 kHz. The boards support Windows 95, 98, and NT applications.

For More Information Circle No. 707



The LogBook/360™ portable **PC-based data acquisition system** from IOtech, Cleveland, OH, is a stand-alone measurement system that includes three internal slots for signal conditioning cards. Optional modem support provides the ability to operate in remote and mobile applications. The 16-bit, 100-kHz system offers multiple channels; the basic unit includes 16 single-ended or 8 differential analog input channels.

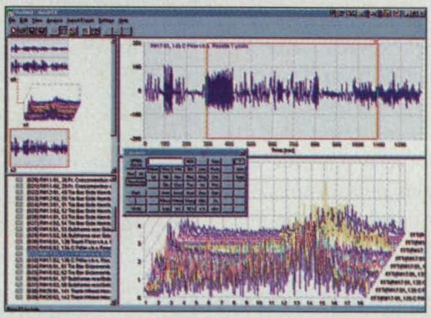
The system also includes 24 general-purpose digital inputs, 4 frequency/pulse counters, 2 frequency/pulse generator outputs, and 4 optional analog outputs. The system internally accommodates up to three signal conditioning options that allow channel capacity to expand to 61 channels of analog input. Channels attach to signals via interchangeable termination panels selected from seven available styles, offering a choice of connector types such as BNC, safety jack, and miniature thermocouple.

For More Information Circle No. 708

The SIR-1000W high-speed, wide-band **digital data recorder** from Sony Precision Technology America, Lake Forest, CA, uses advanced intelligent tape recording technology to collect multi-channel analog and digital data, and digital video. It can record and play back from 2 to 32 hours of high-fidelity analog data at frequency bandwidths to 160 kHz. By using expansion modules and synchronization, a system of virtually any channel count and bandwidth can be configured.

Tape speed for both recording and playback can be set at any of five ranges. The system is equipped with auxiliary channels that allow simultaneous recording and playback of other types of information along with data, including tachometer pulses, verbal annotations, and time code signals. Options include SCSI II computer interfaces.

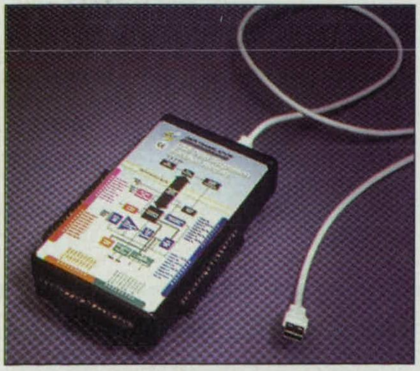
For More Information Circle No. 709



dataACE **data acquisition and analysis software** from Optim Electronics, Germantown, MD, enables engineers to visualize, analyze, and present test data. The 32-bit Windows application offers a menu-controlled user interface and a range of analysis tools and functions, including FFTs, order analysis, and rainflow. The program features statistical functions and a scientific calculator for data analysis in both time and frequency domains.

Automated report generation, using an integrated layout edtior with drag-and-drop functionality, enables creation and publication of reports. Import/export data can be exchanged with industry-standard data formats, such as ASCII and RPCIII.

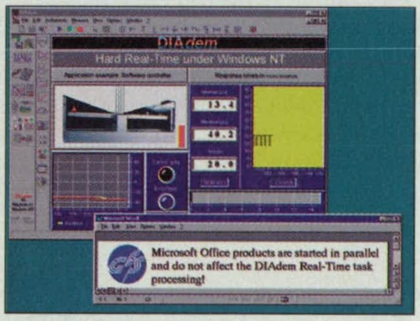
For More Information Circle No. 711



Data Translation, Marlboro, MA, offers the DT9800 Series **USB modules for data acquisition** that provide 16SE/8DI inputs with 12- or 16-bit resolution, up to 100 kS/s throughput, 16 digital I/O lines, and two user counter/timers. Optional 12- or 16-bit analog outputs are available.

The modules require no external power supply; one cable supplies both power and connections to the USB module. They also feature 500V isolation for low-noise measurements. An on-board processor controls and supervises all sub-systems on board. The modules are hot-swappable and may be transported to and from different PCs.

For More Information Circle No. 706



DIAdem® Version 6 real-time **data acquisition and control software** from GfS, Novi, MI, combines Windows NT with real-time timing behavior for acquiring data or controlling test rigs. Depending on the speed performance required, the software offers "soft" and "hard" real time. Both can be implemented with a range of conventional PC plug-in boards, with no modifications to the Windows NT operating system.

Features include icon-based data acquisition and program operation; data acquisition, analysis, and report generation in one program without programming; a modular program structure; and automation of test, analysis, and report generation.

For More Information Circle No. 710

Electronic Components and Systems

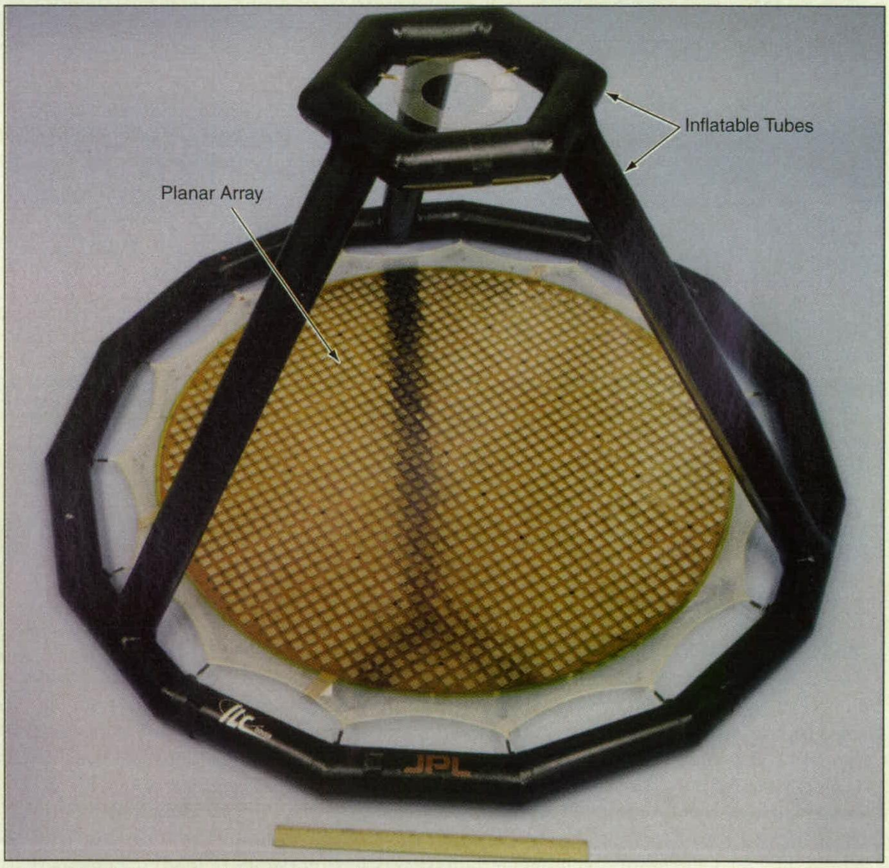
Inflatable Reflectarray Antennas

Reflector surfaces are stretched flat by inflating circular toroidal tubes.

NASA's Jet Propulsion Laboratory, Pasadena, California

A type of reflectarray antenna now undergoing development is based on the concept of a reflector membrane that is stretched flat by attaching it to an inflatable frame (see figure). Antennas of this type are meant to serve as lightweight, compactly stowable, reliable alternatives to conventional antennas with rigid reflector structures or mechanically deployed mesh reflectors. Originally intended for use aboard spacecraft for microwave communications, these antennas might also prove useful in terrestrial low-power, lightweight microwave systems in cases in which reflector-surface distortions caused by gravitation and wind could be tolerated.

The reflectarray in an antenna of this type is a planar array of microstrip patches printed on a thin circular membrane. An inflatable circular toroidal tube is attached to the edge of the membrane; when inflated, the tube stretches the membrane flat and supports the membrane in the operational configuration. Inflatable tripod tubes attached to the inflatable torus serve as struts to support a feed horn that illuminates the reflectarray. The patches of the reflectarray are shaped and sized to make the reflected electromagnetic field cophasal, so that the antenna operates with high gain.



Inflatable Circular Toroidal Tubes stretch the planar array of microstrip patches printed on a circular membrane.

It must be emphasized that surface of an antenna of this type is designed to be flat — in contradistinction to the paraboloidal shape of a conventional antenna reflector. In a previous attempt to deploy an inflatable antenna with a paraboloidal reflector surface, the surface figure deviated from the required paraboloid by far more than the maximum allowable error. In the present case, achievement of the desired precision in the surface figure is not difficult; the desired flatness is readily maintained by stretching the membrane.

A prototype with an overall size of about 1 m, designed for operation in the X band, has been built and tested. The inflatable antenna structure should be mass-producible at low cost.

This work was done by John Huang and Alfonso Feria of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
NPO-20433

GaN-Based Linear Array of Ultraviolet Detectors

This is a solar-blind array that can operate at room temperature.

Goddard Space Flight Center, Greenbelt, Maryland

A recently developed gallium nitride-based linear array of ultraviolet detectors is blind to most of the visible spectrum, with a cutoff wavelength of 370 nm. This device is a prototype of GaN detector arrays for ultraviolet-light imaging in the presence of significant visible radiation, without need for extensive baffling to suppress stray light or for costly filters to block visible light. The volume, weight, and power consumption of this GaN detector array is an

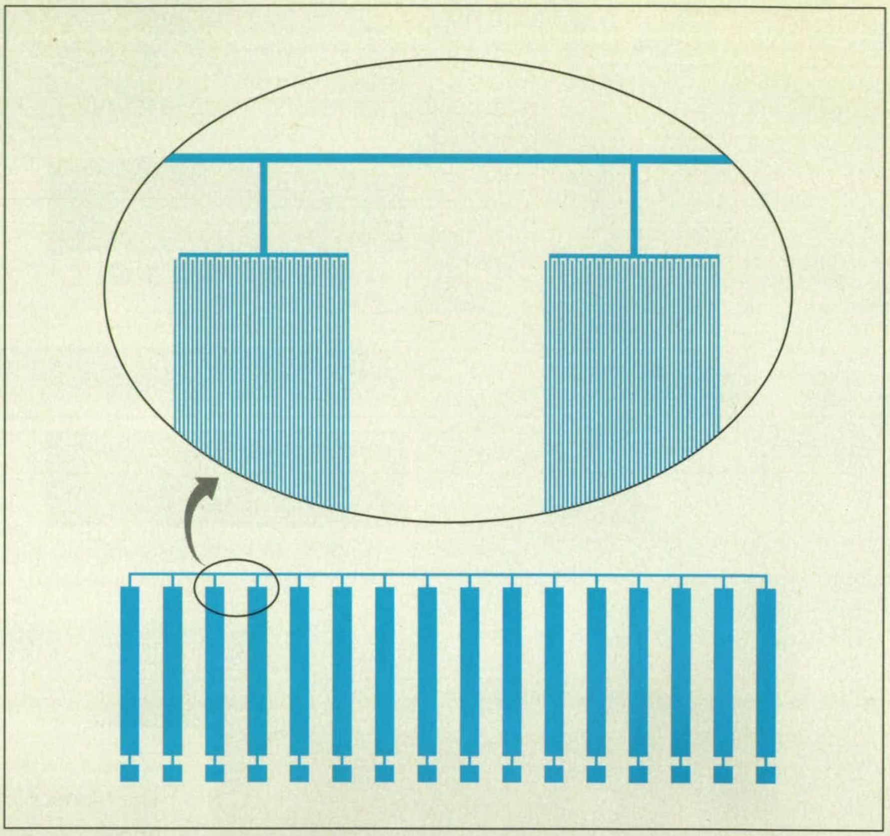


Figure 1. The **Array Contains 16 Elements,** each having an interdigitated metal/semiconductor structure with 20 fingers coming in from each end. The fingers are spaced at intervals of 4 μm. Each finger is 2 μm wide and 500 μm long.

order of magnitude below those of comparable photomultiplier tubes and microchannel plates now used to detect ultraviolet light. This GaN detector array also operates at lower voltage. Moreover, GaN is rugged, and the fabrication of detectors from GaN is relatively easy.

The prototype device — a 1 × 16 array — was fabricated by a conventional lift-off technique. Each detector element comprises a metal/semiconductor/metal interdigitated structure (see Figure 1). The overall area of the array is 4 mm². Semi-insulating GaN was used to obtain low dark current. The metal digits and connecting lines were formed in a Ti/Al/Au multilayer, which was used to ensure good ohmic contact.

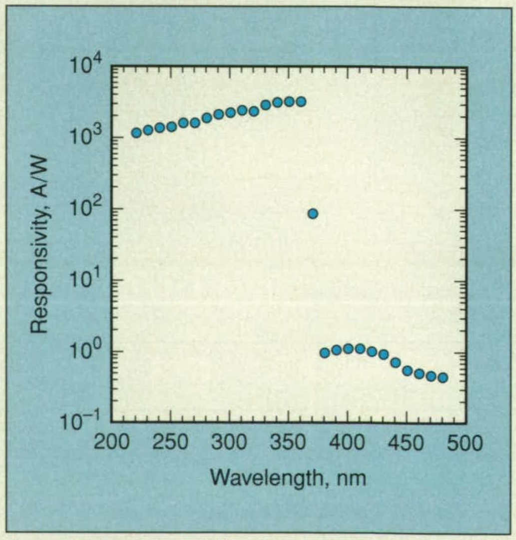


Figure 2. The **Responsivity of One Detector Element** was measured during operation at a potential under 10 V. Note the sharp cutoff at the wavelength of 370 nm.

Figure 2 shows the measured responsivity of one detector element. This detector element was found to have a responsivity of 3.1 ± 0.3 A/W at a wavelength of 365 nm, a response time of 0.5 ± 0.2 ms, and a dark current of 5×10^{-11} A; as of the time of submission of the information for this article, these performance figures were the best yet reported for GaN ultraviolet detectors.

There are numerous potential industrial, medical, and scientific-research applications for GaN detector arrays like this one. For example, because of their solar-blind nature, such arrays would be well suited for geophysical observation. They could also be used to detect ultraviolet light in hot environments and to detect ultraviolet emissions from flames and rocket exhausts.

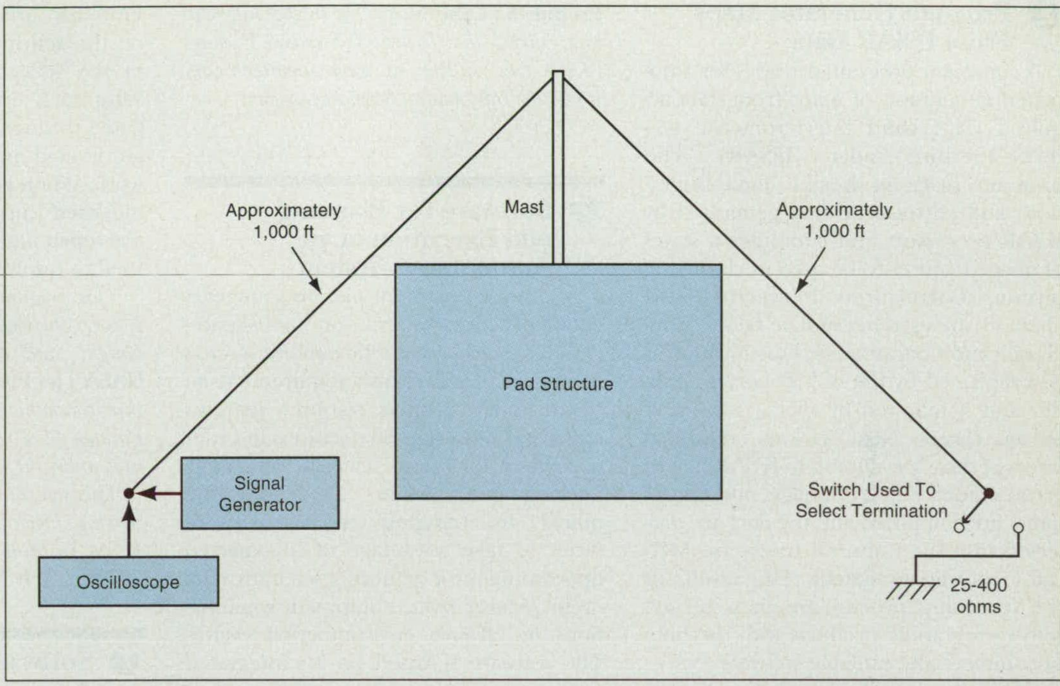
This work was done by Zhenchun Huang, David Brent Mott, and Peter K. Shu of **Goddard Space Flight Center.** *No further documentation is available.*
GSC-13828

Improved Lightning-Current Measurements on a Protective Wire

Transfer functions to correct for reflections are determined from test pulse measurements.

John F. Kennedy Space Center, Florida

A test procedure has been devised to increase the accuracy with which lightning currents on a protective wire can be determined from raw current measurements. The procedure was conceived specifically for determining lightning currents on a steel cable used to protect the space shuttle launch pad against direct lightning strikes. The cable is hung between (a) a mast on top of the launch pad and (b) two grounding points about 1,000 ft (≈300 m) away from the mast.



Pulses Are Applied at One End of the cable and measured after reflection from the other end of the cable with grounded and open-circuit terminations.

The measurements are made by use of current sensors at the grounded ends of the cable. The measured currents are distorted versions of the lightning currents in the following sense: Each section of the cable is, in effect, a lossy transmission line of characteristic impedance Z_0 terminated in impedances different from (and generally smaller than) Z_0. The mismatches between impedances give rise to reflections at the grounded ends and at the mast, so that the measured currents are superpositions of incident and reflected currents. The measurements are further complicated by attenuation (both ohmic and radiation losses) of currents that have traveled along the cable to the measurement points. In general, the characteristic impedance, the ohmic and radiation losses, and the terminating impedances are unknown and are functions of signal frequency.

The problem thus becomes one of determining frequency-dependent reflection coefficients, then using these coefficients to construct a transfer function that expresses the relationship between the raw current measurements and the incident lightning current. The transfer function can then be used, in turn, to correct the measurements for reflections and attenuations to obtain more-accurate estimates of the incident lightning current. The present test procedure (see figure) yields the needed reflection-coefficient information, without need for explicit knowledge of the unknown impedances and losses. The steps of the procedure are the following:

1. One end of the cable is disconnected from ground, creating an open-circuit (infinite-impedance) termination. The other end is connected to ground through a 50-Ω resistor.
2. A pulse with a duration of about 250 ns is applied across the resistor. About 5 μs later, this pulse returns after reflection from the open-circuit end. Because of losses, the amplitude of the returned waveform is less than that of the applied waveform. An oscilloscope at the resistor is used to observe and record the applied and returned waveforms.
3. The returned waveform is Fourier-transformed to obtain a complex spectral amplitude $S_{open}(\omega)$, where $\omega \equiv 2\pi \times$ frequency.
4. The end opposite the resistor is connected to ground, creating a nearly short-circuit (low-impedance) termination.
5. A measurement like that of step 2 is performed. Because the impedance of the termination is less than Z_0, the polarity of the returned waveform is the reverse of that observed with the open-circuit termination.
6. The returned waveform is Fourier-transformed to obtain second complex spectral amplitude, $S_{grounded}(\omega)$.
7. The ratio $S_{grounded}(\omega)/S_{open}(\omega)$ is then calculated. This ratio is one of two desired frequency-dependent reflection coefficients.
8. The terminations and test equipment at the two ends of the cable are interchanged and steps 1 through 7 are performed to obtain the other frequency-dependent reflection coefficient; that is, $S_{grounded}(\omega)/S_{open}(\omega)$ for measurements from the opposite end.

This work was done by Pedro J. Medelius formerly of I-NET, Inc., for **Kennedy Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (407) 867-2544. Refer to KSC-11952.

Software

Program Generates Maps From IFSAR Data

A computer program provides for automated generation of maps from data acquired via C-band interferometric synthetic-aperture radar (IFSAR). The program reads in height, radar-brightness, and correlation data generated by IFSAR processors and computes a series of image features to be used in classifying terrain. Correlations between IFSAR channels are used to estimate new terrain-classification parameters. Classification is accomplished by use of a Bayesian classifier and is followed by spatial editing of terrain classes. Next, various additional layers of data (pertaining to IFSAR height error, shaded relief, drainage, and mountains) are computed and the data are projected into the universal transverse Mercator coordinate system. The results of the foregoing process are then turned into cartographic products with the help of commercially available software.

This program was written by Ernesto Rodriguez, Thierry Michel, Jan Martin, and Bijan Houshmand of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*
NPO-20325

Software for Planning and Execution in an Autonomous System

A software system for planning and execution of actions by an autonomous spacecraft engaged in scientific exploration has been developed to satisfy requirements to (1) maintain positive resource margins and avoid short-sighted decisions in order to achieve long-term scientific and engineering goals while (2) responding quickly to changing circumstances in order to take advantage of unexpected opportunities for gathering scientific data or to recover from equipment malfunctions or adverse environmental events. The software is based on an integrated planning-and-execution architecture that supports continuous modification of a current working plan in response to continuously arriving updated information on the activities, resources, and the state of the spacecraft and its environment. After each update, its effects are propagated through current projections, which are limited in order to avoid unnecessary work. When conflicts arise in the plan as modified pursuant to the updates, iterative repair and local-search techniques are used to resolve the conflicts.

This program was written by Steve Chien, Robert Sherwood, Gregg Rabideau, Russell Knight, and Andre Stechert of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20590.

Software Library for Parallel Adaptive Mesh Refinement

A software library has been developed for use in parallel adaptive refinement of unstructured (irregular) meshes and grids in parallel scientific and engineering computing. This library can be used in finite-difference, finite-volume, and finite-element application programs that use two-dimensional triangular meshes or three-dimensional tetrahedral meshes. The library contains a suite of well designed and efficiently implemented modules that perform common operations in a parallel-adaptive-mesh-refinement (PAMR) process. These operations include (1) quality control during a successive PAMR process, typically guided by a local-error-estimate algorithm; and (2) parallel dynamic load-balancing of an adaptive mesh. The library was implemented in Fortran 90 and uses a message-passing-interface (MPI) library to support modularity, efficiency, and portability. The library is currently available on a Cray T3E computer at the Goddard Space Flight Center, and is being ported to a cluster of personal computers (a Beowulf-class system).

This program was written by John Z. Lou and Charles D. Norton of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*
NPO-20583

Algor, Inc.
150 Beta Drive, Pittsburgh, PA 15238-2932 USA
Phone: +1 (412) 967-2700
Fax: +1 (412) 967-2781
California: +1 (714) 564-0844
Europe (UK): +44 (1784) 442 246
Email: info@algor.com
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Materials

Cheaper Polymeric Electrolyte Membranes for Fuel Cells

In addition to costing less, these membranes resist methanol crossover.

NASA's Jet Propulsion Laboratory, Pasadena, California

Proton-conductive (solid-electrolyte) membranes made from sulfonated poly(phenylether sulfone), plus membrane/electrode assemblies containing these membranes, have been developed for use in methanol fuel cells. These membranes offer two important advantages over traditional fuel-cell membranes made of a commercial perfluorosulfonic acid-based ion-exchange polymer:

1. Whereas the traditional membranes cost about $900/m^2 (as of 1997), the present membranes are expected to cost between $5/m^2 and $10/m^2.
2. The traditional membranes are somewhat permeable by methanol; crossover by methanol is a parasitic process that reduces fuel-cell efficiency. The present membranes offer greater resistance to methanol crossover.

The figure illustrates the synthesis of sulfonated poly(phenylether sulfone). Degrees of sulfonation can be controlled to obtain polymers of various equivalent molecular weights. Any of these polymers or a mixture of them can be dissolved in dimethyl formamide (DMF) to form a casting "dope." Other ingredients can be added to the mixture to modify the properties of the membranes to be formed subsequently. To form a membrane, one casts the dope on a suitable surface in air, by use of a casting apparatus with a doctor blade.

Of the membranes of this kind tested thus far, the best one was made from a 75-percent portion of sulfonated poly(phenylether sulfone) of 620 daltons equivalent molecular weight plus a 25-percent portion of the unsulfonated base polymer. The incorporation of the unsulfonated base polymer adds strength and reduces crossover, relative to the pure sulfonated polymer. The casting dope formed by dissolving this mixture of polymers in DMF is not a true solution and, instead, appears to be more like an emulsion.

Casting twice has been found to be essential to formation of a stable dope and casting of a useful membrane. On first casting, the dope separates into what are presumed to be ionomeric (sulfonated) and inert (unsulfonated) phases. The polymer as thus cast is redissolved in DMF to form a new dope. Upon casting from the new dope, phase separation does not occur; the precise physicochemical mechanism responsible for this phenomenon has not been established, though it has been conjectured to be a consequence of absorption of a small amount of water from the air immediately after the first casting.

The fabrication of a membrane/electrode assembly includes, among other things, hot-pressing a membrane between carbon papers that have been coated with electrode-catalyst/liquid-ionomer mixtures, with the coated sides in contact with the membrane. To achieve adequate adhesion between the anode and the membrane, it is necessary to modify the anode-side membrane surface, prior to hot pressing, by rubbing it with a small amount of carbon-supported anode catalyst.

The electrical characteristics of fuel cells containing membrane/electrode assemblies of this type are similar to those of similarly dimensioned fuel cells containing traditional membrane/electrode assemblies. However, the present membrane/electrode assemblies operate with less methanol crossover; for example, the membrane/electrode assembly made with the best membrane exhibited about as much methanol crossover as would be expected of a membrane/electrode assembly containing a traditional membrane of three times the thickness.

This work was done by Shiao-Ping Yen, Andrew Kindler, Andre Yavrouian, and Gerald Halpert of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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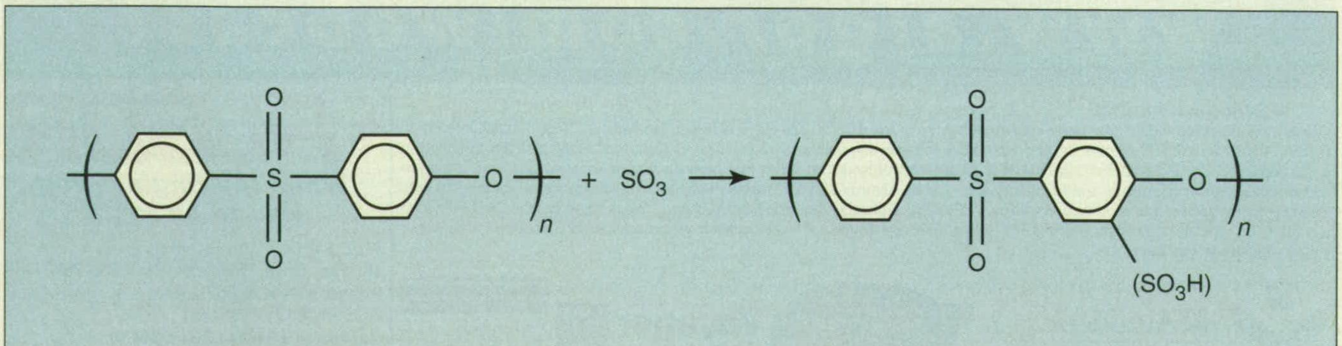
Refer to NPO-20251, volume and number of this NASA Tech Briefs *issue, and the page number.*



Sulfonated Poly(Phenylether Sulfone) is Synthesized by sulfonation of a sulfonated poly(phenylether sulfone) base polymer with sulfur trioxide in the presence of methylene chloride.

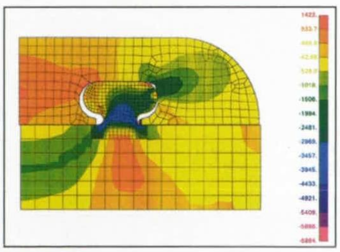
AST news

AEROSPACE SEALING TECHNOLOGY Volume 12 No. 2

Next Generation Landing Gear Seals Split-Lock™* Backup Ring Development IMPROVES INSTALLATION PROCEDURE and In Service Effectiveness of ACT™ Ring

The Split-Lock™ design development was driven by installation concerns, expressed by Airline users, when assembling multi piece split backup ring components, into landing gear seal carriers, under field maintenance conditions.

The Split-Lock™ uses the same axial thickness for each ring as previously designed staged backup rings. It also uses the same "forgiving" PTFE inboard backup with a high modulus outboard backup ring as part of the succesfull staged concept. The key design feature mechanically joins the individual backup rings as a unit assembly to form a "single" solid or endless ring. The ring set will then provide a concentric fit within the seal cavity, for ease of assembly as the seal carrier is guided over the inner cylinder during OEM builds. For field replacement, when the seal carrier is lowered out of the shock strut housing, the ring halves can be articulated around its circumference so that the cut ends meet and the unit assembly opens as a conventional scarf cut backup ring. The ring set can then be indexed together so the individual splits are staggered and then easily guided down the inner cylinder into the open ended seal cavity.



Significant dynamic in-house testing indicated success prior to installation in the field.

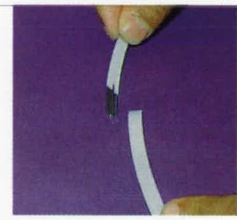
Nonlinear Finite Element Analysis (FEA), conducted in-house, indicated there are "NO" shear strength related issues at the site of the dovetail lock area.

The Split-Lock™ has been proven to protect the elastomeric component in demanding, high response, high pressure applications such as Main Landing Gear and Nose Landing Gear.

Greene, Tweed is committed to best practice design to provide the most effective in-service performance in terms of sealing effectiveness, efficiency and maintenance of aerospace systems. The Split-Lock™ is a significant development which will do just this; reducing maintenance turnaround times and increasing effectiveness of installation and consequently ensuring consistent seal performance.

*Patent Pending

In-Use Concerns Regarding Installation And Operation Of Normal Backup Rings



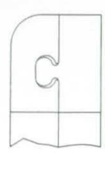
Usually the inboard backup ring is designed with a radius to mate effectively with the elastomer. Under reverse installation, where the backups are inadvertently installed the wrong way around, the elastomer can be damaged causing seal leakage in some instances.

Field maintenance conditions often make successful installation of a five-piece seal assembly (one elastomer, four backup rings) a challenge because of the following:

- Scarf cuts must be staggered 180° and mated properly to allow effective anti-extrusion action.
- Backup Rings will stress relieve so there can be overlap at the scarf cut again causing backup failure or seal damage.
- Scarf ends are sometimes sheared during the blind assembly.
- Improper placement of backups down within the carrier inhibits the placement of the elastomeric component of the seal.

Since the outboard backup ring is usually manufactured from a Nylon based material, the hygroscopic nature of the material can result in dimensional growth under humid storage conditions.

The use of single high modulus NWR, ARLON, PEEK, and filled PTFE instead of staged backup rings has proven to be abrasive against the elastomeric component of the seal.

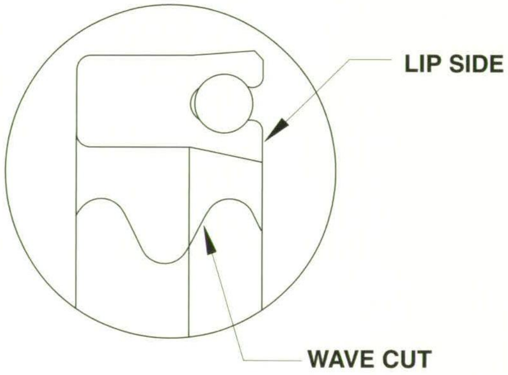


Wave-Cut RSA Scraper Development Provides An Effective Split Wiper Option For Landing Gear Field Repairs

The normal configuration of the RSA Scraper is solid. This design avoids any particle ingression path ensuring effective scraping action. The endless design is not conducive for field replacement within housing gland nuts while positioned on the inner cylinder. Greene, Tweed's design solution is a controlled, Wave-Cut RSA scraper. A sectional drawing is given below.

The design uses the same RSA Scraper configuration as the existing solid (uncut) designs. The same energizer O-Ring and scraper jacket materials are available. The Wave-Cut design "blocks" the dirt ingression path and also provides added stability during installation. There is no effective gap with the wave cut design due to a compressive fit within the gland.

Controlled, in-house, dynamic dirt ingression testing, has proven the effectiveness of the Wave-Cut RSA Scraper design. Consult Greene, Tweed application engineers for full details.



In-Use Concerns Regarding Installation And Operation Of Scraper Rings In Landing Gear Systems

The Wave-Cut RSA Scraper design was driven by installation concerns expressed by Airlines.

Solid Scrapers are not conducive for field installation without the full separation of the landing gear strut. This is not always possible or desirable in maintenance operations.

Diester-based grease is present during Landing Gear overhaul. Use of incompatible O-Ring energizers causes volume swell of the O-Ring. This can cause it to snap out of the Urethane jacket after installation. Greene, Tweed's design solution is a Urethane based O-Ring compatible with diester-based grease (Code "G" Energizer).

Conclusion

The ease of installation has been proven on the Wave-Cut RSA Scraper design. The integrity of the mating cut plane has been confirmed before, during, and after installation and testing.

The dimensional change noted before and after testing is the same for RSA Solid and Wave-Cut RSA Scraper designs. Solid scrapers outperform split scrapers in terms of scraper efficiency as would be expected; however, the Wave-Cut RSA scraper meets the dirt ingression requirements associated with Landing Gear testing.

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GREENE, TWEED & CO.
2075 Detwiler Road, P.O. Box 305
Kulpsville, PA 19443, USA
Tel: + 1 (215) 256 9521
Fax: + 1 (215) 256 0189

GREENE, TWEED & CO.
Aerospace & Defense Division
1555 Bustard Road, Suite 130
P.O. Box 217, Kulpsville, PA 19443-0217, USA
Tel: + 1 (215) 256 9521
Fax:+ 1 (215) 412 2980

GREENE, TWEED & CO.
ADVANTEC Division
7101 Patterson Drive
Garden Grove, CA 92841 USA
Tel: + 1 (714) 893 0903
Fax:+ 1 (714) 373 1763

GREENE, TWEED & CO. LTD.
Finch Close, Nottingham, NG7 2NN
United Kingdom
Tel: + 44 (0) 115 986 6555
Fax:+ 44 (0) 115 986 6235

GREENE, TWEED & CO. FRANCE S.A.
19 rue des Beaux Soleils
BP 409 Osny
95527 Cergy Pontoise
Cedex, France
Tel: + 33 (1) 30 73 54 44
Fax:+ 33 (1) 30 73 45 75

GREENE, TWEED & CO. GmbH
Nordring 22, 65719 Hofheim, Germany
Tel: + 49 (0) 61 92 92 99 50
Fax:+ 49 (0) 61 92 90 03 16

GREENE, TWEED & CO. Pte. LTD.
21 Serangoon North Avenue 5
#04-1/03 Ban Teck Han Building
Singapore 544864
Tel: + 65 481 2808
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GREENE, TWEED & CO. JAPAN
4F, Furointo-Mita Building 14-5
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Japan
Tel: + 81 (3) 3454 1050
Fax:+ 81 (3) 3454 1040

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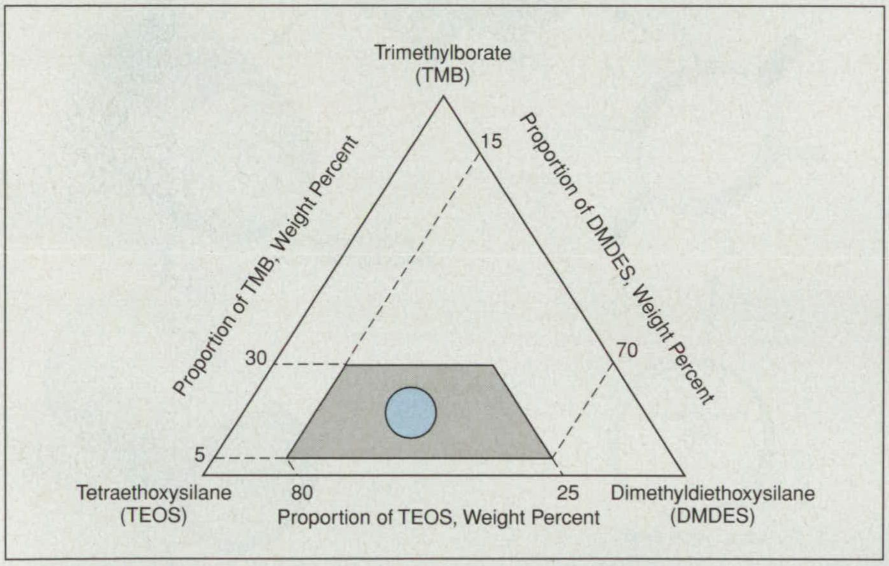
Lightweight, Oxidation-Resistant $C_wSi_xO_yB_z$ Ceramics

Ceramic precursors are made by sol-gel impregnation of carbon preforms.

Ames Research Center, Moffett Field, California

Lightweight, monolithic ceramics that retain their shapes and strengths and resist oxidation at temperatures up to 1,200 °C have been invented. These ceramics are made of carbon, silicon, oxygen, and boron. These ceramics are made by (1) using a sol-gel process to infiltrate noncarbon ingredients into lightweight, porous carbon preforms; then (2) pyrolizing the infiltrated preforms.

A suitable carbon preform could be a piece of felt or boardstock, for example. Inasmuch as the finished monolithic ceramic article has the same size and shape as those of the preform, it is usually advantageous to start with a preform of the desired net size and shape.



The **Trapezoid on This Ternary Diagram** encloses the range of proportions of three typical ingredients that can be used to make sols according to this invention. The range of optimum proportions is enclosed by the circle.

In the sol-gel process used in this invention, the preform is immersed in a sol that comprises a mixture of silicon alkoxides and a borate ester (typically di- and tetrafunctional siloxanes and a boron alkoxide), then the sol is gelled in place. (Gelation comprises simultaneous hydrolysis and polymerization reactions.) The sol is prepared by mixing the siloxane and boron alkoxide reagents (see figure), preferably with an alcohol as a diluent. The alcohol prevents premature hydrolysis of the sol and ensures homogeneity of the sol.

Although the sol can be gelled by aging at ambient temperature or by heating, it is preferable to catalyze gelation by addition of an acid (e.g., HNO_3) or a base (e.g., NH_4OH) to the reaction mixture. Gelation of the catalyzed sol eventually occurs at ambient temperature, but it is further preferable to heat the impregnated preform gently to a temperature between 40 and 90 °C.

After gelation, the impregnated preform is removed from the gel and any surplus gel adhering to the preform is wiped off. The impregnated preform is then dried to form a ceramic precursor; preferably, the drying is done in a vacuum oven overnight at a temperature between 70 and 100 °C to ensure that all volatiles are removed before the pyrolysis step described next.

The dried, impregnated preform is heated in an inert gas (e.g., argon) or in a vacuum, preferably at a temperature between 900 and 1,200 °C. During this heating process, the carbon of the preform enters into pyrolysis reactions with the dried gel and thereby becomes part of the ceramic.

This work was done by Daniel B. Leiser, Ming-ta Hsu, and Timothy S. Chen of **Ames Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

This invention has been patented by NASA (U.S. Patent No. 5,618,766). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center; (650) 604-5104. Refer to ARC-12096.

Shrouds Would Catch Debris From Disintegrating Machines

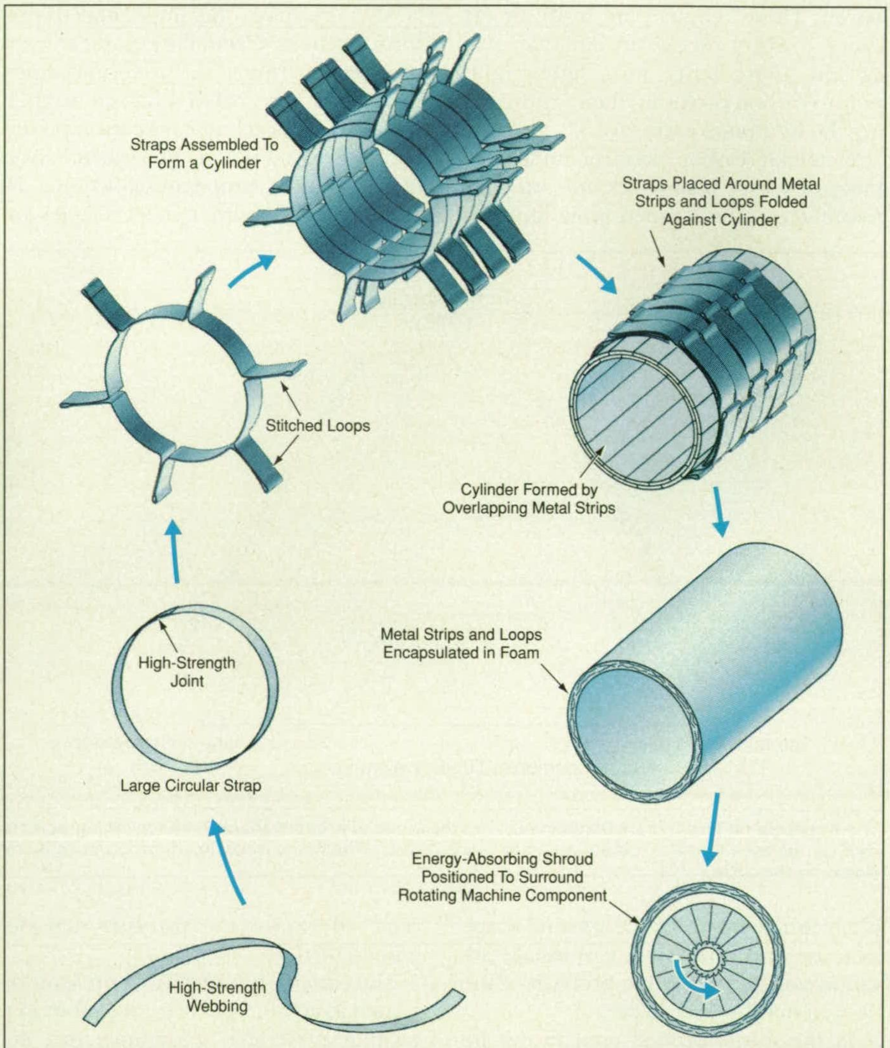
Kinetic energy of debris would be transformed into controlled breakage of shroud materials.

Lyndon B. Johnson Space Center, Houston, Texas

Kinetic-energy-absorbing shrouds have been proposed to protect nearby persons and equipment against high-speed debris ejected by disintegrating machines. Examples of machines that could eject high-speed debris include turbines and gyroscopes. The shrouds would be laminated composites of several materials that would be designed to transform the kinetic energy of impinging debris into controlled, progressive breakage of the materials, so that the debris would become trapped harmlessly within the shrouds.

Each shroud (see figure) would contain two layers of overlapping longitudinal metal strips surrounded by circular straps made of a strong webbing material (e.g., made from aromatic polyamide fibers). Before wrapping around the cylinder defined by the metal strips, each strap would have a circumference greater than that of the cylinder. Each strap would be sized to fit snugly on the cylinder in the following way: At numerous equidistant points around the circumference, the strap would be doubled to form loops that would be sewn together with a stitch that would rip apart by an applied load slightly below the breaking strength of the webbing itself. Thus, the straps would be capable of absorbing energy in a controlled manner by progressive ripping of the stitches.

All the looped straps thus fabricated would be assembled side by side over the cylinder of metal strips. The sewn loops would be folded to lie circumferentially against the outer surface. Depending on the specific design, another subassembly comprising another two layers of metal strips and another layer of straps with sewn loops could be formed around the previous one. The entire assembly would then be encapsulated in a rigid, low-strength foam, thereby forming a unitary energy-absorbing cylinder that would be mounted around the rotating component that posed a disintegration hazard.



A **Multilayer Composite-Material Cylinder** would be fabricated, then placed around a rotating machine component to catch debris from disintegration of the component.

Upon disintegration of the rotating component, fragments of the component would first impinge on the metal strips, forcing them into the energy-absorbing straps. The force in each affected strap would increase until it reached the ripping load, at which point the stitches in the loops would begin to come apart. During this process, the foam would break, allowing the straps to react to the force. The total energy absorbed in this way would be approximately equal to the product of the ripping force and the displacement of each strap. If the shroud were to contain multiple layers (in contradistinction to a single layer) of energy-absorbing straps, the overall radial displacement could be limited to a smaller value because each layer of straps would absorb a fraction of the total energy.

This work was done by William C. Schneider of **Johnson Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22823.

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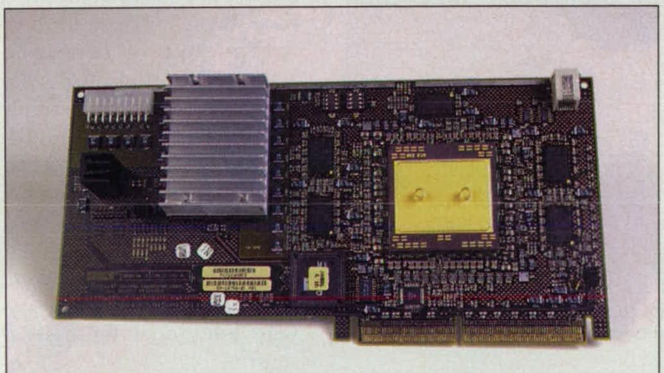
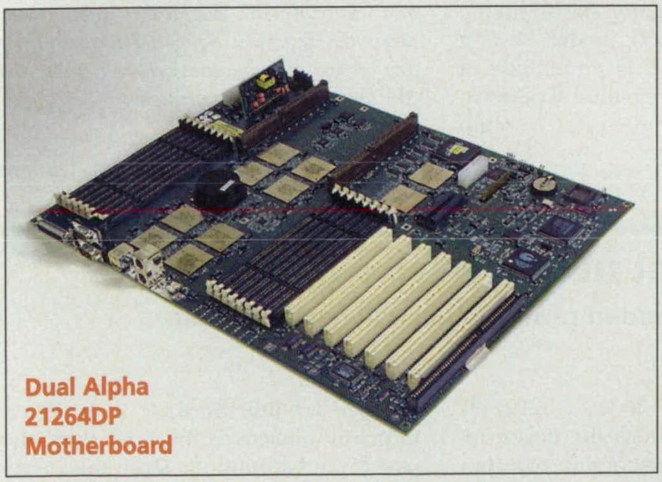


667MHZ Alpha 21264 Daughtercard



Dual Alpha 21264DP Motherboard

Company History

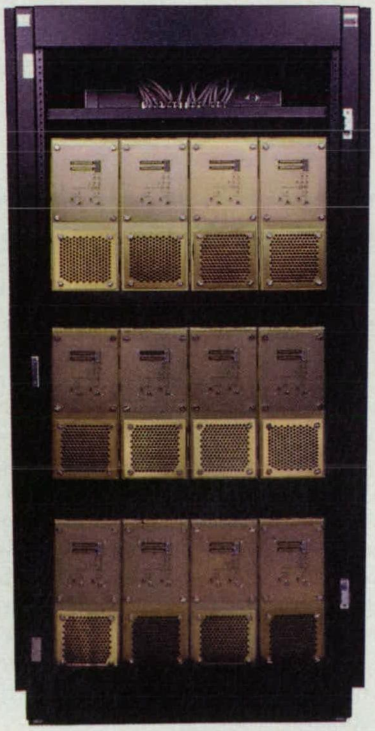
Microway was founded in 1982 to help scientists and engineers take advantage of the IBM PC. Our first product was a library, which made it possible to use an 8087 in a PC. We bundled our libraries with 8087s and became one of Intel's largest customers.

Our hardware products included PC accelerators, coprocessor cards, and motherboards. In 1986, we introduced the first 32-bit Fortran to run on an Intel PC. The first PC to hit a megaflop used a Microway/Weitek coprocessor driven by NDP Fortran. Over the years, NDP Fortran has been used to port hundreds of popular mainframe applications, including MATLAB and ASPEN, to Intel-based PCs.

Microway's workstations have been purchased by university and NASA laboratories since 1989. *PC Computing Magazine* named our Alpha system "the fastest Windows NT workstation on the planet ... the performance leader."

For more information, contact Microway, Inc., Research Park, Box 79, Kingston, MA 02364; Tel: 508-746-7341; Fax: 508-746-4678; e-mail: info@microway.com; www.microway.com

Microway 24 Node Linux Beowulf Cluster



Machinery/Automation

Model X-33 Subscale Flight Research Program

This program advances the development of the X-33 and the art of model flight testing.

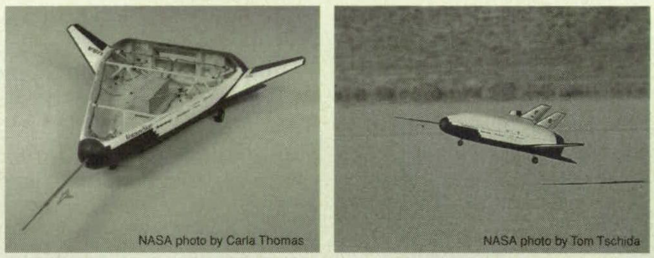
Dryden Flight Research Center, Edwards, California

A program of flight testing of an instrumented subscale model of the X-33 aerospace vehicle is underway. The objectives of this program are the following:

- Successful flight of a model of the X-33;
- Development of a small, lightweight, instrumentation system suitable for model research;
- Determination of limited X-33 aerodynamic characteristics from flight data; and
- Quantification of how well parameter-estimation techniques perform when applied to data acquired by use of the lightweight instrumentation system on a model of this type.

The program is justified by the fact that model flight-testing often highlights unforeseen characteristics, and by the potential for applying the flight-test techniques and instrumentation developed in this program to flight testing of other subscale, lightly loaded models of aerospace vehicles.

The X-33 model (see figure) is 4 ft (1.2 m) long and was fabricated in the landing-gear-down configuration. The model has been flown 29 times to date, and 16 channels of instrumentation were in use during the last 20 flights. The model weighs 8 lb (3.6 kg) empty and 11 lb (5 kg) with instrumentation. The 3-lb (1.4-kg) instrumentation system, developed specifically for the X-33 model, includes a power supply, sensors, and related wiring. The model is visually controlled from the ground and has no stability augmentation. Because of its limited performance, stability, and control, the X-33 configuration is a challenging one to fly and land.



The **X-33 Model** is instrumented for flight tests in which it is launched at altitude, then descends and lands on the ground.

A typical flight operation starts with the launching of the X-33 model from a larger, powered model at an altitude of 1,000 ft (305 m). There is time to perform one flight-data maneuver prior to setup for landing. The model is back on the ground about 25 seconds after launch. The flight data are then downloaded into a laptop computer. The flights thus far have been used to mature the hardware, establish the best combination of vehicle trim and center of gravity, and gather limited flight data.

Some of the flight data gathered thus far have been analyzed. Several maneuvers have been successfully analyzed by use of parameter-estimation techniques. Moments of inertia were recently experimentally determined. A detailed calibration of air-data parameters will soon follow, and further analyses of flight data will be performed once the calibration is complete. There are plans to evaluate additional lightweight sensors.

This work was done by Alex G. Sim and Jim Murray of **Dryden Flight Research Center** *and Tony Frackowiak of Analytical Services and Materials, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*
DRC-99-22

Device Assists Actuation of a Joint in a Pressure Suit

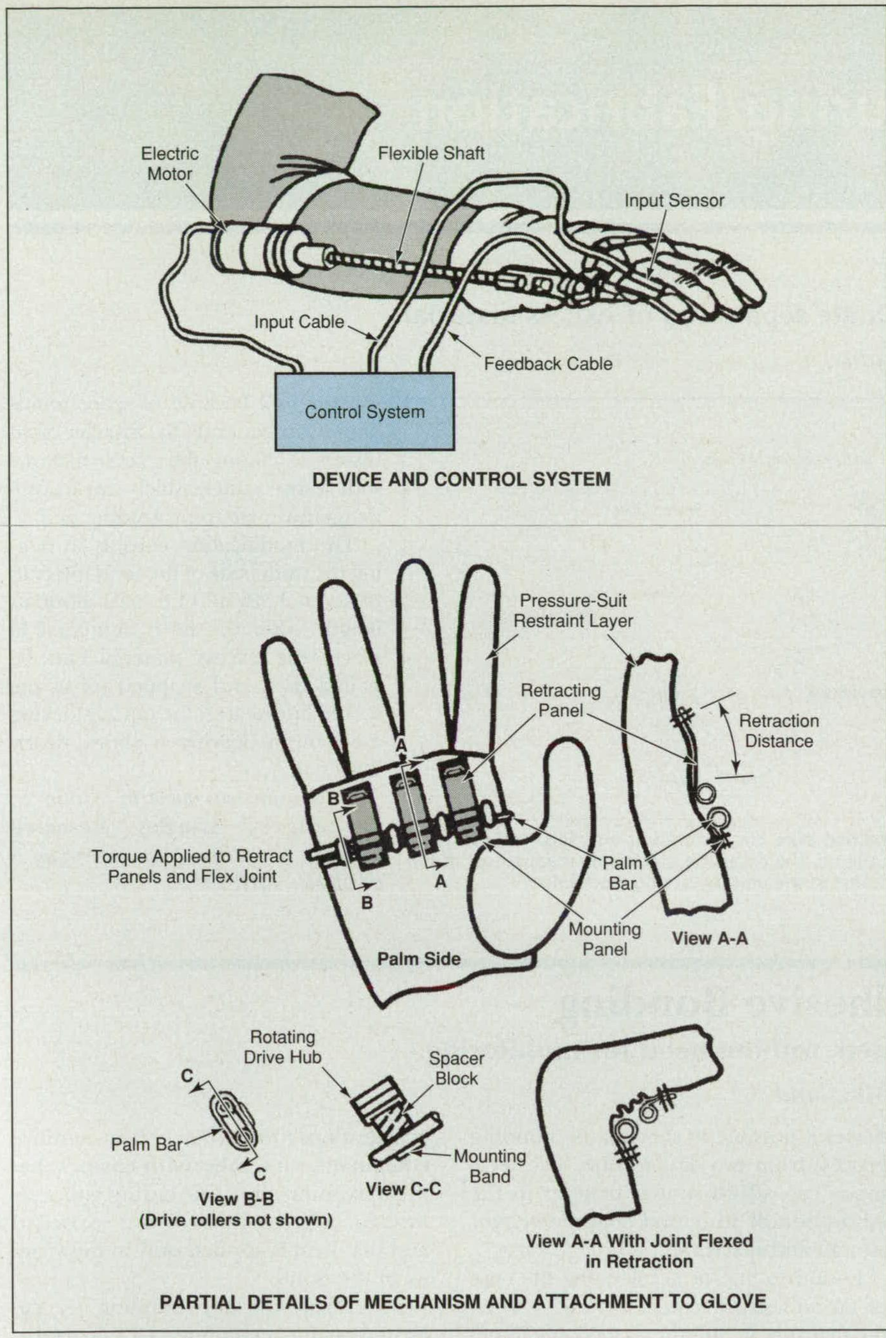
The full range of motion can be restored when human power is partially or fully lost.

Lyndon B. Johnson Space Center, Houston, Texas

An electromechanical device implements a unique method of actuating a fabric joint in an inflatable structure — in particular, the joint in an astronaut's pressure suit. The method is based on the principle that power from an external source can be applied to a non-constant-volume joint in a pressure suit to actuate the joint without human force. Actuation of the joint by power from an external power source enables the astronaut to conserve energy for tasks that require more dexterity.

The design of the device is relatively simple. The figure shows the device installed as part of a pressure-suit glove, but the device can be applied to any similar inflatable structure. A drive shaft made of flexible cable or rigid segments, driven via internal and external ball hex couplings, is positioned to intersect a palm bar, which is on the palm side of the glove at the metacarpal joint. The drive shaft goes through several drive hubs, rotating within mountings that include a band and a spacer block. Retracting panels are wrapped around the drive shaft. When torque is applied via the drive shaft, the panels wind around the shaft; this causes the panels to pull on anchor points, thereby retracting the joint (closing the palm). Thus, by use of this device, the wearer can flex the metacarpal joint without using any muscle power.

An input sensor positioned either inside or outside the pressure suit exhibits changing electrical resistance in response to control movement of the wearer's hand. The sensor output signal is fed as



This **Electromechanical Device Attached to a Pressure-Suit Glove** uses power from an external source to assist the wearer in flexing the metacarpal (palm) joint. In response to the wearer's hand motion, the input sensor generates an input to the control system.

input to an external control system that drives an electric motor. The motor, in turn, drives the flexible shaft and a gear drive unit. A feedback sensor is incorporated into the gear drive unit for additional response.

This device is potentially applicable beyond the U. S. Space Program. Devices like this one could easily be applied to other pressure-suit joints, or could be used on inflatable mobility joints for individuals who suffer from joint diseases and have partially or fully lost the use of the affected joints. The device could restore the full range of motion to a diseased joint or optimize the motility of a healthy joint being used under extreme conditions like zero gravity. In a case of therapeutic use on an inflated mobility joint to restore movement to a nonfunctioning limb, the input sensor could be placed on another limb or digit that is functional. Clearly, this device is a significant advance in the field of bionics and of potential benefit to both public and private sectors.

This work was done by Daniel G. Cencer of **Johnson Space Center**. *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22797.

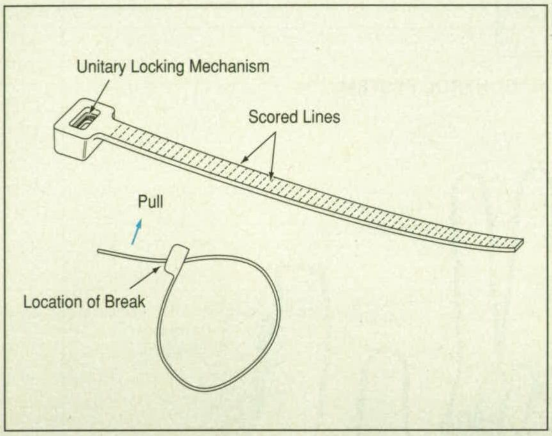
Manufacturing/Fabrication

Modified Wire Tie

The modified tie is scored to facilitate separation of excess material.

Langley Research Center, Hampton, Virginia

A common self-locking plastic wire tie has been modified (see figure) to enable the installer to snap off excess tie material after installation, without need for a cutting tool and without creating a potentially hazardous sharp end. A typical unmodified wire tie of this type is available in any of a variety of sizes and is made of nylon or another plastic. When the unmodified tie is tightened around a bundle of wires or other object, the excess tie material (the material that protrudes from a unitary locking mechanism at one end of the tie) must be cut off flush with the locking mechanism by use of a special tool. Often, an installer does not possess such a tool or cannot use the tool because of space limitations. Consequently, the installer often resorts to cutting the excess material with a wire cutter, which can leave a dangerously sharp protruding end.



The **Modified Wire Tie** is scored at intervals. After installation of the tie, the excess tie material is snapped off at the score closest to the unitary locking mechanism.

The modification consists in scoring the underside of the tie at intervals of about 1/16 in. (1.6 mm) along its length. After the tie is tightened in place, the excess material can be pulled back and snapped off at the scored line nearest the unitary locking mechanism, leaving a short, nearly flush end.

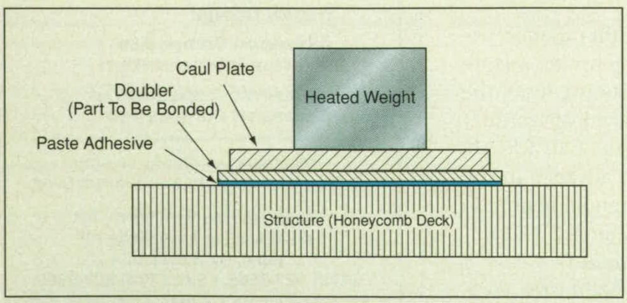
This work was done by Arthur R. Hayhurst of **Langley Research Center.** *No further documentation is available. LAR-15103*

Heated Weights for Adhesive Bonding

The risk of overheating is eliminated, without need for monitoring.

Goddard Space Flight Center, Greenbelt, Maryland

Heated weights have been found to be useful in adhesive bonding of clips, doublers, and other small parts to lightweight structures and structural components (e.g., face-sheet/honeycomb-core sandwich panels). The heated weights provide both the heat needed to accelerate curing of the adhesive and the force needed to clamp the bonded parts together until the cure is complete.



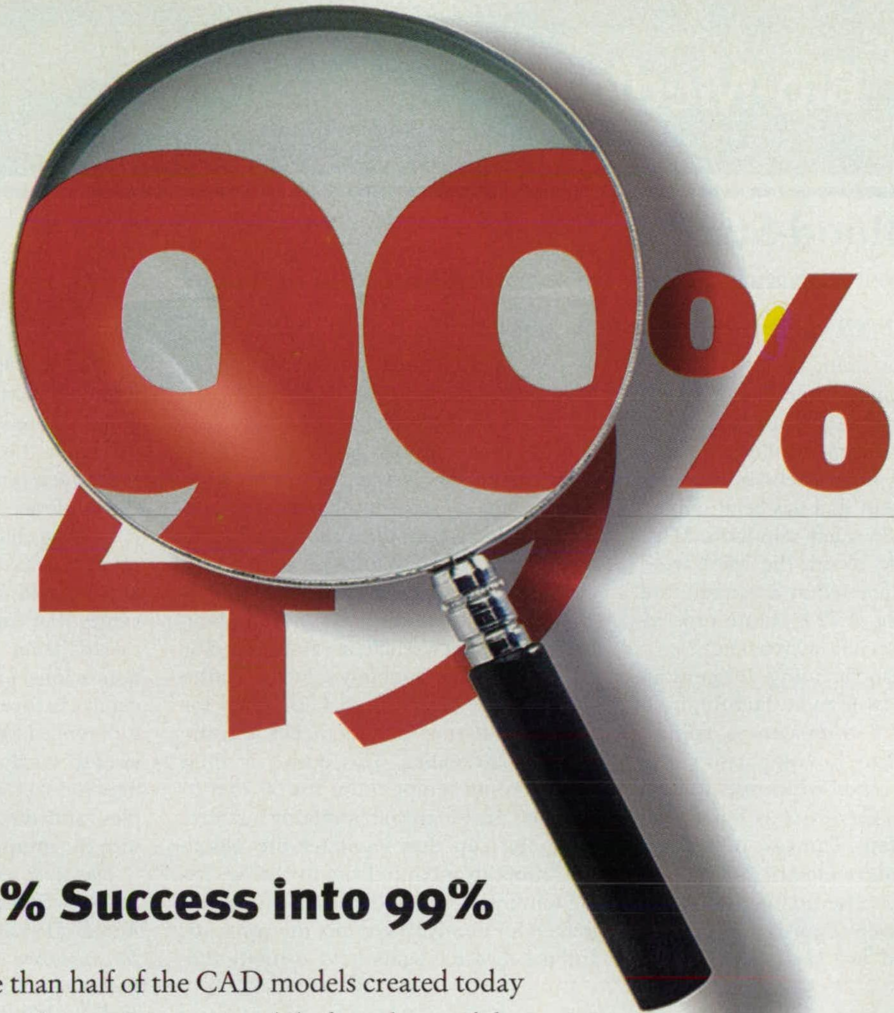
Heat From the Weight is coupled through the caul plate to the part to be bonded.

The heated-weight technique was developed in support of the Top Hat Balloon Project, wherein the technique is used to accelerate the cure of a paste adhesive for bonding inserts. The technique makes it possible to shorten the bonding process from two days to one. The technique can afford similar benefits in the fabrication of structural components for aircraft and spacecraft.

Local heating for accelerating the cure of an adhesive becomes necessary when the structure in question is too large to put in an oven or when heat-sensitive equipment has already been installed on the structure. Therefore, local heating has commonly been accomplished by use of heat lamps or electric heating blankets, and clamping forces have been applied by weights, clamps, or vacuum bags. Heat lamps or electric blankets must be monitored closely to ensure that maximum allowable curing temperatures are not exceeded, and heat-sensitive equipment must be removed or protected. In contrast, the heated-weight technique does not require close monitoring or special preparations to protect heat-sensitive equipment, yet it inherently ensures that the maximum allowable curing temperature for a given bond is not exceeded and that heat is applied only in the vicinity of the bond.

In preparation for bonding by the heated-weight technique, a caul plate is machined from a highly thermally conductive material (e.g., aluminum or copper) to the profile of the small part to be bonded to a structure. In an oven, a suitable weight is preheated to a temperature equal to or less than the maximum allowable curing temperature for the adhesive used in the bond. The caul plate is placed on the part to be bonded, and the heated weight is placed on top of the caul plate (see figure). The caul plate distributes the weight and heat evenly over the part. If additional heating time is needed to complete the cure, then additional weights can be heated and used to replace the previous heated weight(s).

This work was done by James Parker and David Puckett of **Goddard Space Flight Center**. *No further documentation is available. GSC-13866*



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For More Information Circle No. 564

Whole-Blood-Staining Device

This inexpensive, hand-held device is robust and self-contained.

Lyndon B. Johnson Space Center, Houston, Texas

A whole-blood-staining device provides a means of (1) staining white blood cells by use of monoclonal antibodies conjugated to various fluorochromes, followed by (2) lysing and fixing of the cells by use of a commercial reagent that has been diluted according to NASA safety standards. More stable than whole blood, the lysed/fixed cells can be refrigerated at a temperature of 4 °C for as long as 72 h before processing and analysis on a flow cytometer.

This whole-blood-staining device is inexpensive and easy to manufacture. It offers advantages of compactness, robustness, and simplicity in comparison with equipment developed previously for the same purpose. The device is hand-held and self-contained. The use of the device does not require electric power, precise mixing, or precise incubation times.

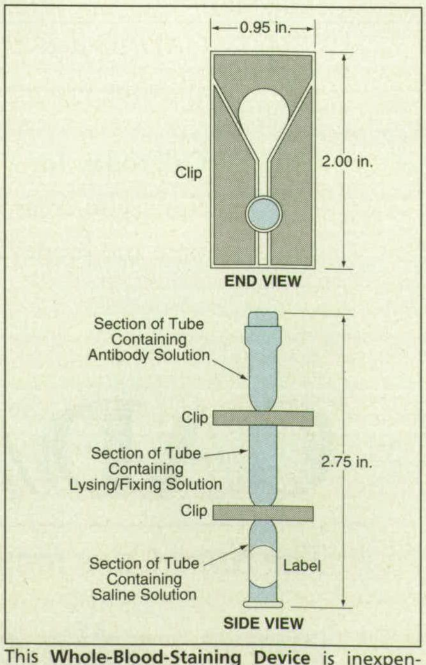
The device (see figure) includes a reagent tube and two clips that separate the reagent tube into three compartments. During manufacture, the three compartments are loaded with (1) a solution containing the staining antibodies, (2) a lysing/fixing solution, and (3) a buffered saline solution, respectively. The first section, which contains the antibody solution, is equipped with a septum through which the blood sample can be injected.

At the time and place of sampling, 100 μL of anticoagulated whole blood is injected into the antibody solution via the septum. The device is shaken gently for about 10 s to mix the blood cells with the staining antibodies. The device is then held at room temperature for 30 min to incubate the blood-cell/antibody mixture. Next, the clip that separates the blood-cell/antibody mixture from the lysing/fixing solution is removed, the device is again shaken for about 10 s to mix the contents, and the device is again held at room temperature for 30 min. Then the other clip is removed and the device is shaken for about 10 s to mix in the saline solution. At this point, the device is refrigerated to preserve the mixture until further processing.

The device was developed for use in ascertaining changes in the immune systems of astronauts during long space flights. It is also suitable for use on Earth in small facilities that cannot afford expensive automated lysing equipment, large stocks of monoclonal-antibody reagents that could expire before use, and flow cytometers. Reference laboratories could send the devices to small rural facilities or doctors' offices for staining and lysing of blood samples, and the devices could be returned with the samples for analysis.

This work was done by Clarence F. Sams of **Johnson Space Center**; *Vaughan Clift and Kelly E. McDonald of Martin Marietta Services, Inc.; and Ellen Meinelt of Krug Life Sciences. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Bio-Medical category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-4871. Refer to MSC-22614.



This **Whole-Blood-Staining Device** is inexpensive, simple, and easy to use.

October 1999

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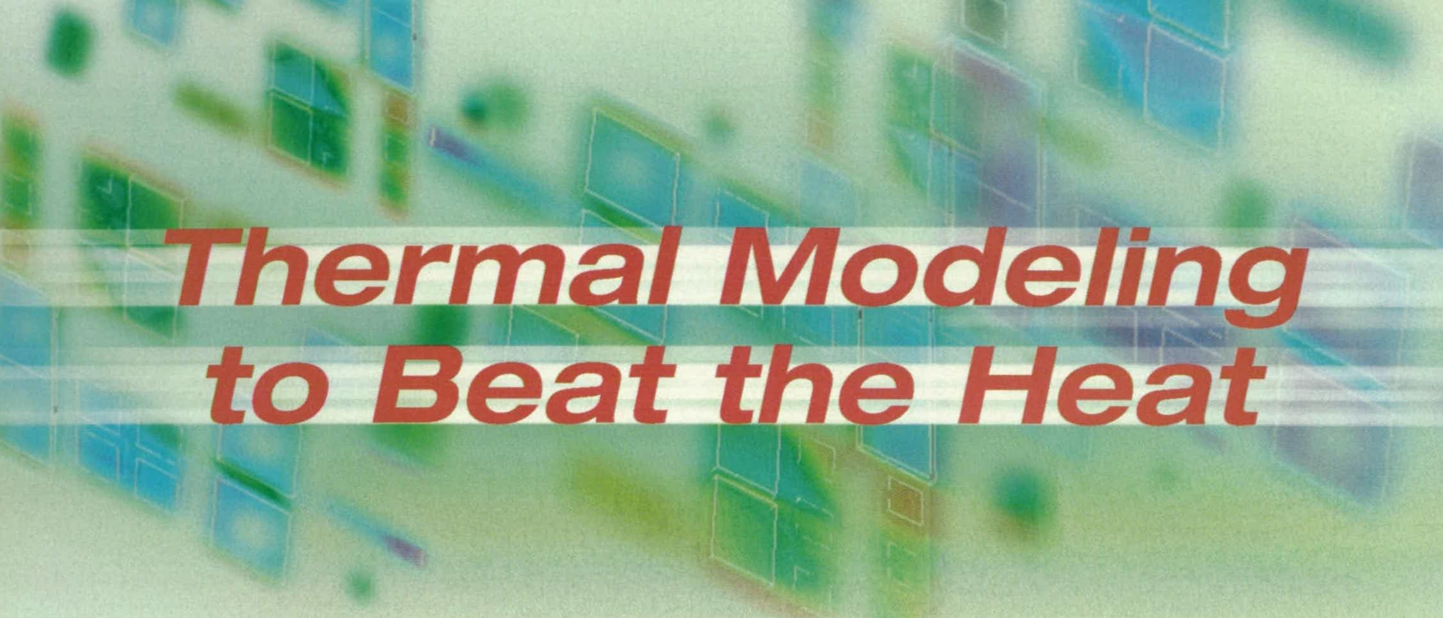
ELECTRONICS TECH BRIEFS

Photo courtesy of Morton Advanced Materials. See "New Products."



Thermal Modeling to Beat the Heat

Applying computational fluid dynamics to PC-board design reveals how system components relate to one another thermally.

As integrated circuits (ICs) decrease in size and the amount of heat they generate increases, placement on the printed circuit board (PCB) and the interrelationship of system components with one another become critical. Chips on an overheated board have a much shorter lifetime than those on one that deals with the heat problem, and they may malfunction. Computational fluid dynamics (CFD) thermal modeling software is an invaluable tool for the board designer, helping him to quickly and easily understand component interrelationships and how their placement affects the thermal dynamics of the system. Applying CFD software for thermal management from the outset of the design process can ensure PCBs get the cooling they require, even in the tight spacing demanded by the Peripheral Component Interconnect (PCI) and CompactPCI standards.[1]

When an engineer is designing a new or improved piece of electronic equipment, there are three demands to keep in balance: the electrical demands of the circuit, the thermal demands of the components, and the end-user demands on the product as a whole. Once the capability requirements of the major system components have been defined, the designer begins the thermal design. The first step in optimizing board-level cooling is to understand board placement in the overall system. If a board is designed to mount vertically, for example, a hot IC mounted at the bottom of the board will heat up all the devices directly above it. In many cases, the location of the system fan and the power supply are fixed in advance, dictating the airflow direction over the board. Understanding

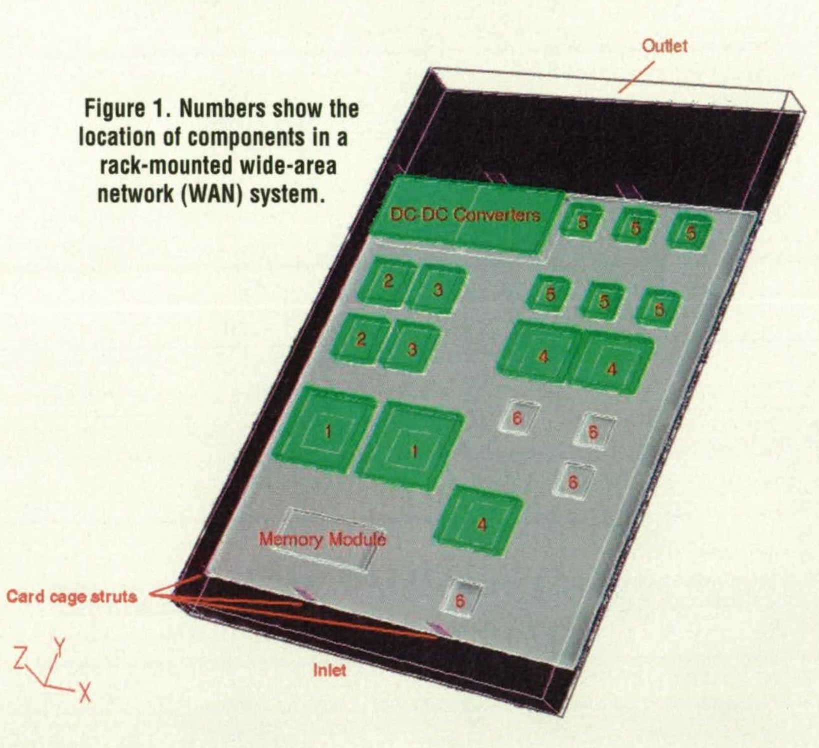


Figure 1. Numbers show the location of components in a rack-mounted wide-area network (WAN) system.

Footnote

1. The PCI standard was approved by the PCI Special Interest Group, and the CompactPCI standard was developed by the PCI Industrial Computer Manufacturers Group.

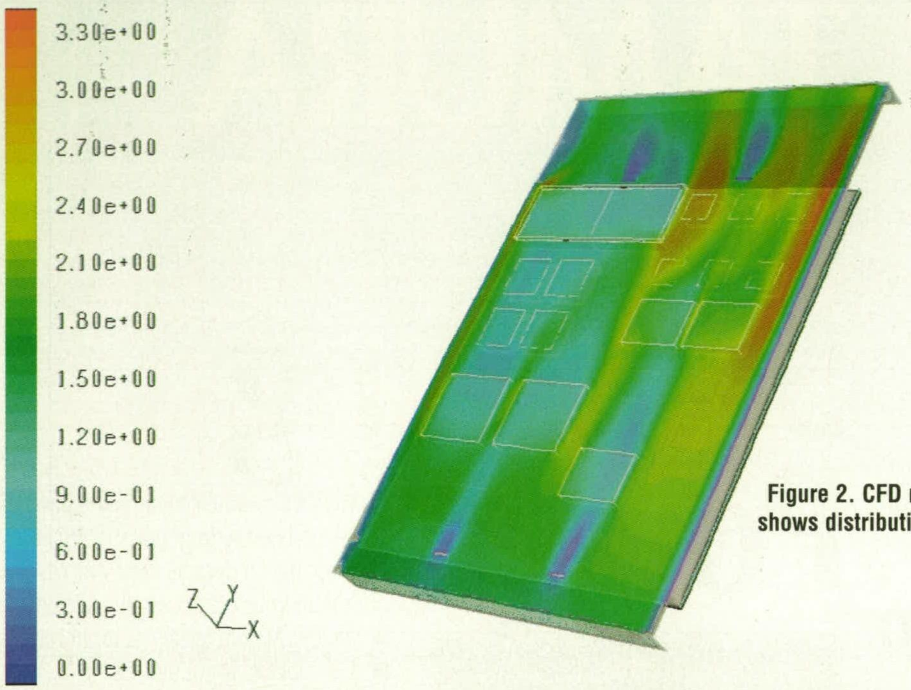


Figure 2. CFD model of airflow shows distribution over the board.

the mounting position and the airflow direction provides the designer with the backbone of the cooling solution and key parameters for thermal modeling.

Modeling lends insight

CFD software can model several different component layouts rapidly, giving the designer insight into how competing component arrangements affect the totality. This basic information ensures that thermal requirements form part of the basis for component placement before the design is set in stone.

Advanced thermal modeling plays a role at the most basic levels of PCB design—board layout, mapping, utilization of system airflow, and design of heat sinks and other cooling mechanisms. Using CFD software, PCB designers can extend computer-aided design into the prototyping and testing function, thus saving considerable time and expense. With CFD, designers build a virtual prototype of the system and test the airflow and heat distribution at both the board and the system levels. Some CFD modeling programs, such as Fluent's Icepak, are designed specifically for this purpose. With 'plug-and-play' fans, heat sinks, ICs, and other components, the designer can build prototypes, change them, and test them

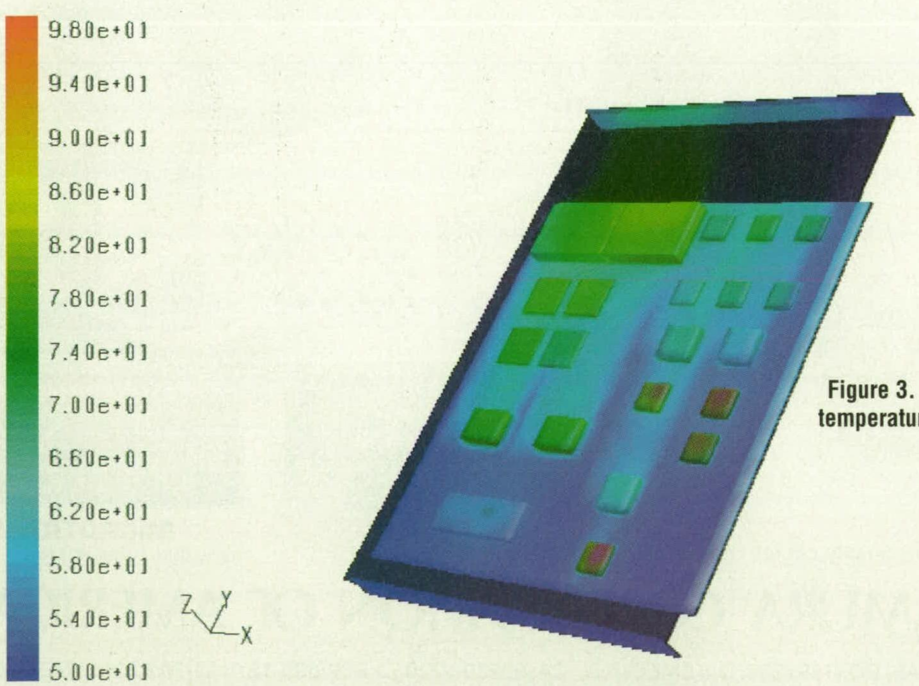


Figure 3. CFD model shows temperature gradients.

again, until the results are optimal. These programs also provide connectivity with electronic design analysis (EDA) and computer-aided design (CAD) tools, so that information can be shared throughout the computer-aided engineering (CAE) process.

Cooling a WAN system

A developer of a rack-mounted wide-area network (WAN) system needed to determine if the selected heat sinks would adequately cool approximately 150 watts dissipated by the components on the board. Figure 1 shows the component layout of the system.

In the previous design of the WAN system, the worst-case slot received 33 cubic feet per minute (cfm) of air at 50 °C. The initial design had heat sinks on five of the six ICs and on the DC-DC converter, with no heat sink on the sixth IC or the memory module.

Using Icepak CFD software to analyze the system's airflow allowed the designers to understand the cooling mechanism for each heat sink. The deep blue color in Figure 2 shows the areas without airflow behind the struts. The height of the DC-DC converters obstructs the airflow, forcing it to bypass the majority of the board's area to the right. The yellow in the figure shows higher air velocity. Figure 3 shows that most of the components would remain cool, but the 3-watt components (labeled 6 in Figure 1) would be too hot. These were the devices with no heat sinks. Adding small heat sinks to the 3-watt devices brought their maximum junction temperature below specification and allowed the selection of smaller heat sinks for some of the cooler devices.

Performing the analysis during the design phase of the project obviated the need for short-term solutions or lengthy prototyping. The manufacturer was also able to reduce the overall cost of the thermal components by using smaller, less expensive heat sinks than those originally specified.

A small footprint

Another company's goal was to further distinguish itself in the highly competitive power-conversion market with the smallest cabinet footprint. The 225 kVA inverter under development needed to fit within a standard cabinet. Cabinet width was the only dimension that could be varied. Since the thermal solution for the PCB often dictates the footprint in this type of application, they used CFD modeling to establish the optimum solution.

After using Icepak CFD software to help select the fan system that would supply sufficient airflow, the designers performed additional CFD analysis to assess how the heat sinks would work within the system framework. The program aided them in determining the number of heat sinks that could be arrayed in parallel with a single fan, and the number that could be arrayed in series with a single fan. Either way, the design could take advantage of a thyristor grouping in which they were arranged in decreasing heat-power levels. Based on the analysis, the resulting board maximized the cooling in a small cabinet with two fewer fans than originally anticipated. The consequent thermal solution surpassed the manufacturer's requirements for both size and cost.

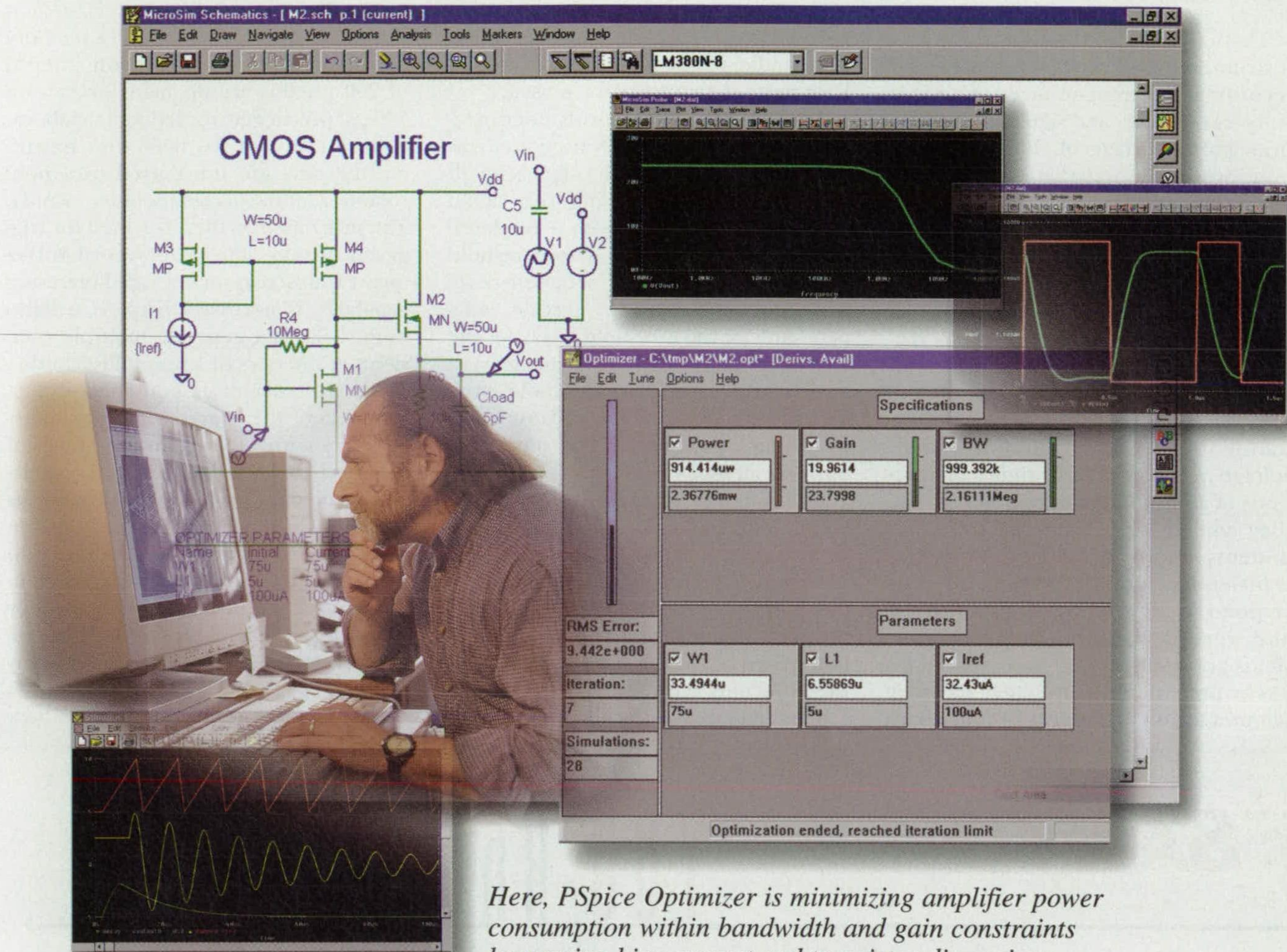
In another application, CFD analysis showed the most critical chip on a video card was overheating, at 15 °C over specification. Without CFD, this might not have been caught until after the prototype was completed, since the proximity of other heat-generating devices contributed to the elevated operating temperature. The use of Icepak software for thirty minutes, however, allowed the designers to select and test a heat sink that brought the device temperature down to 5 °C below specification.

Cutting time to market

With reduced time to market as a primary consideration for product-line profitability, shortening the time devoted to thermal management must be a leading design requirement. The use of CFD software in the design phase shows the effects of board placement and airflow on the thermal dynamics of the PCB. Thermal design through modeling eliminates the need for prototyping at each design phase, significantly improving time to market. CFD is compressing the design cycle and resulting in better thermal management for less cost for electronics designers worldwide.

For more information, please contact the authors of this article, Dr. Prabhu Sathyamurthy of Fluent Inc., 10 Cavendish Court, Lebanon, NH 03766; (603) 643-2600; E-mail: pss@fluent.fluent.com; or Dr. Vivek Mansingh at Applied Thermal Technologies, 3255 Kifer Rd., Santa Clara, CA 95051; (408) 522-8730; fax (408) 522-8729; E-mail: mansingh@applied.fluent.com.

Don't Just Simulate Your Design.



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For More Information Circle No. 482

Fast Transient-Voltage Recorder

This instrument responds rapidly enough to record transients induced by lightning.

John F. Kennedy Space Center, Florida

The figure schematically illustrates an instrument designed expressly for recording lightning-induced transient voltages on power and signal cables. The principal advantage of this instrument over previously available transient-voltage recorders is high speed, as explained below.

Transient voltages generated by large electric motors and switching of power equipment consist primarily of spectral components well below a frequency of 1 MHz. Most commercial transient-voltage recorders can detect and record such transients. However, transients induced by lightning feature voltage peaks with rise times of fractions of a microsecond; in other words, they contain significant spectral components above 1 MHz. Commercial transient-voltage recorders do not respond rapidly enough to measure and record lightning-induced transients accurately.

The present transient-voltage recorder samples transient voltages in four channels at a rate of 20 MHz. The instrument can handle a peak input potential of 50 V, or more if an attenuator is used.

A microprocessor controls the operation of the instrument. A trigger circuit continuously monitors the signals on all four channels, comparing the signal level on each channel with a predetermined threshold level. The threshold for each channel can be set at any level from 5 to 95 percent of full scale, independently of the threshold levels for the other channels. When the signal level in any channel exceeds its threshold level, a trigger signal is generated, causing full recording of data to begin simultaneously on all four channels.

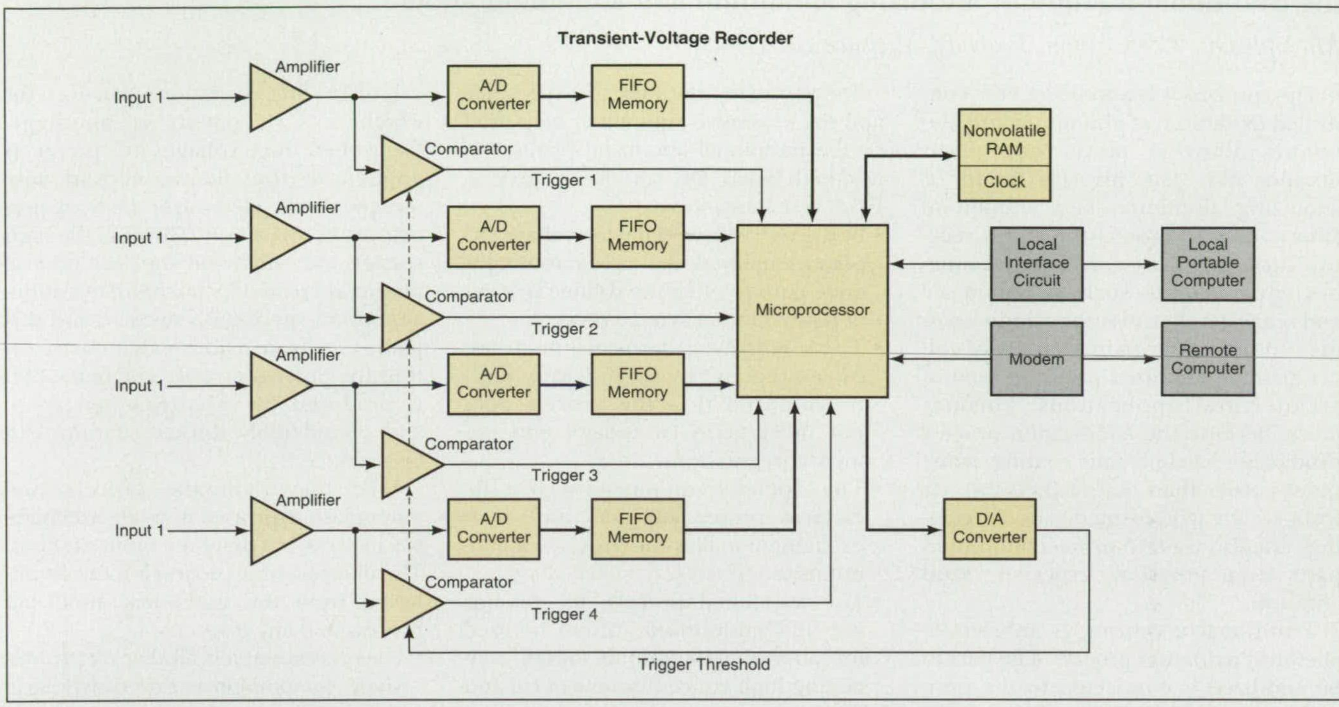
Even when data are not being recorded fully, the analog-to-digital (A/D) converters in the four channels operate continuously, temporarily storing their output data in first-in/first-out (FIFO) memory circuits that are always kept half full. When a trigger signal is received, the remaining halves of the FIFO memories are filled up with data. Inasmuch as the full capacity of each FIFO memory corresponds to an observation interval of 200 μs, this arrangement provides a 100-μs pretrigger recording capability. Once a transient has been thus recorded, the data are transferred to a nonvolatile random-access memory (RAM). The instrument is then rearmed for triggering within 400 μs to record subsequent transients; such a rapid-rearming capability is necessary because a lightning strike can generate multiple transients at intervals of a few milliseconds.

The instrument is equipped with a clock, and the stored data are time-coded, not only to establish the times of transients but also to facilitate correlation with data on the same transients measured by other instruments. Data on as many as 15 transients can be stored in the RAM. The data are retrieved from the nonvolatile RAM, either locally by use of a portable computer and a standard interface circuit, or remotely through a modem. The instrument is normally powered through an ordinary

ac power line but also contains batteries to enable it to operate as long as 16 hours in case of ac-power failure. The nonvolatile RAM retains its data even when the batteries have been depleted.

This work was done by Howard James Simpson and Pedro J. Medelius formerly of I-NET, Inc., for **Kennedy Space Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center; (407) 867-2544. Refer to KSC-11991.



This **Transient-Voltage Recorder** offers rapid-sampling, pretrigger recording, and rapid-rearming capabilities needed for accurate recording of lightning-induced transients.

Microplasmic Coating Shows High Resistance to Wear, Heat and Corrosion

An innovative electrochemical micro-arc oxidation process improves on the traditional method of anodizing aluminum and aluminum alloys.

Microplasmic Corporation, Peabody, Massachusetts

The process of anodizing, or controlled oxidation, of aluminum and aluminum alloys is more than seven decades old. The primary intent of anodizing aluminum and aluminum-alloy parts is to protect the highly reactive surface against corrosion in aqueous environments, such as humid air and sea water. Because the anodic coating can be produced in a variety of colors, painted anodized parts are used in architectural applications. Furthermore, because the anodization process produces a hard ceramic coating, many times harder than that of the substrate from which it is formed, anodic coatings are also used to protect aluminum parts from abrasion, especially sand abrasion.

Traditional anodizing is an electrochemical oxidation process. The part to be anodized is connected to the positive terminal of a DC power source and a nonreactive metal, such as stainless steel, is connected to the negative terminal. The aluminum part, which is the anode, and the stainless steel cathode are immersed in an electrolytic bath and a DC voltage is applied across them. The potential difference is of the order of 20-100 V, and the current densities are 1-10 A/dm^2. The electrolytic baths comprise aqueous solutions of chromic acid, orthophosphoric acid, sulfuric acid, oxalic acid, or combinations thereof. Because the electrolytic baths have appreciable resistivity, and because the anodization process itself is exothermic, the temperature of the electrolytic bath increases greatly during anodizing. Since the anodizing process is quite sensitive to temperature, the bath temperature is controlled rather closely by a heat exchanger or refrigeration equipment.

Today's advanced anodizing technologies include several proprietary hard-anodizing processes that employ a wide range of electrolyte compositions and operating conditions, and a limited number of aluminum alloy compositions. The type and thickness of coating obtained greatly depend on these three factors. The military specification MIL-A-8625F, for example, lists at least six types and two classes of electrolytically formed anodic coatings on aluminum and aluminum alloys for nonarchitectural applications.

Despite many decades of experience and the expensive equipment employed by the traditional anodizing plants, the acid-bath-based DC anodizing process has severe limitations:

- By the very nature of the low-voltage DC power employed, the anodic coating is quite porous: often the volume percent of pores is as much as 50 percent.
- The electrolytic baths are made up of extremely low-pH acidic electrolytes, and thus the process does not meet many of today's environmental regulations.
- The expensive equipment, such as the electric power supplies and heat exchanger, makes the process capital-intensive.
- The traditional process, for reasons not fully understood, cannot be used for anodizing aluminum alloys containing high concentrations of Cu and Si. Thus many aerospace and automotive parts cannot be satisfactorily anodized, if at all.
- The present process, while appropriate for a limited range of the wrought-aluminum alloys, cannot be used for anodizing other reactive metals, such as Ti, Zr, Mg, etc., and intermetallic compounds and metal-matrix composites. Thus, most of the promising aluminum-based advanced alloys and composites cannot be protected by the traditional anodizing process.
- Above all, the hardness of even the so-called hard anodic coatings is far below the hardness of alpha-alumina, the principal component of the anodic coating. Accordingly the full strength potential of the anodic layer cannot be realized by the traditional process. Indeed, the other potentially beneficial properties of aluminum oxide, such as the high thermal and electrical resistivities and the high dielectric breakdown strength, are not even addressed.

This state of affairs is primarily due to the porosity of the coating produced by the traditional acid-based electrolytic processes at low power levels, and to a certain extent the poor bonding between the aluminum-alloy substrate and the anodic layer.

In recent years the Microplasmic Corporation has developed a unique anodizing technology, called the microplasmic process, for all types of aluminum alloys. It is an electrochemical micro-arc oxidation process (for which a U.S. patent is pending). Controlled high-voltage AC power is applied to the aluminum part submerged in an electrolytic bath of proprietary composition. Through the high voltage and high current, an intense plasma is created by micro-arcing at the aluminum specimen's surface, and this plasma in turn oxidizes that surface—thus the process's name. The oxide film is produced by subsurface oxidation, and considerably thicker coatings can be produced.

Like the traditional process, the microplasmic process is an electrochemical process, but there the similarity ends. The microplasmic process is radically different from the traditional anodizing process in many respects:

- The process employs alkaline electrolytes whose composition is extremely critical to the coating rate and the properties of the anodic film that is formed. The pH of the electrolyte is in the range of 8-12 and thus is environmentally sound.
- The process employs AC at high voltage and high current. Because of the high voltage, a microplasma surrounds the electrodes and the oxygen ions produced in the plasma diffuse through the anodic film into the aluminum substrate to react and form more anodic film.
- The high voltage and high current enable the production of anodic films of the same thickness as that of the traditional process in a fraction of the time.
- Because the voltages are higher than the breakdown voltage of the film formed, open channels are not necessary for sustaining the process and hence dense, thick layers of nonporous film can be readily formed.
- Because the process employs AC power, its productivity is increased.
- The power from an electrical utility supply can be used with proper controls to the electrochemical tank, thus making the process less capital-intensive. There is no need for power rectification or waveform smoothing.
- The temperature of the electrolytic bath need not be precisely maintained. Successful coatings can be obtained even if the temperature excursions are as much as 10-20 °C, further simplifying the process. (*Continued*)

- Above all, unlike with the traditional anodization process, aluminum alloy parts of any composition can be successfully anodized by the microplasmic process. Even more importantly, a variety of ceramic "alloy" coatings, such as Al_2O_3-SiO_2, Al_2O_3-MgO, Al_2O_3-CaO, etc., can only be produced by the microplasmic process.
- The microplasmic process is also suited for hard-coating the inside surface of a part, for example cylindrical, conical, or spherical hollow parts. Many coating processes in the marketplace, such as chemical vapor deposition (CVD), physical vapor deposition (PVD), plasma-enhanced chemical vapor deposition (PECVD), sputtering, thermal spraying, etc., are unable to coat the inside surface of a long part.

Because the microplasmic process produces a thick, well bonded ceramic coating on a variety of reactive light metal alloys, it can be used for a broad range of applications. The primary application might be the replacement of heavier metallic alloys or the more expensive composite materials required by the aerospace and automotive industries by light metals (*e.g.*, Al, Ti, Mg and their alloys) coated by the process. Other applications might be found in the chemical, mechanical, thermal, electrical, and electronics industries.

The ceramic coating can resist both aqueous and moderately high temperature, and is resistant to strong acids and bases. Thus it can be used in the chemical and food processing industries.

The hardness of the film is more than 1300 kg/mm^2, and thus it can be used to resist mechanical sliding, abrasive, and erosive wear. In addition the coefficient of friction is low, and thus it can be used in marginally lubricated systems.

The thermal conductivity of the anodic film is much less than that of metals. Thus anodized parts can be used to maintain uniform distribution of temperature, and to resist thermal shock.

The dielectric breakdown strength of the microplasmic film is comparable to that of alpha Al_2O_3, and hence the coating can be used as an insulating film on electrical and electronic components.

Additionally, the microplasmic process is also well suited for hard-coating interior surfaces, recesses, blind holes, threaded sections, and so on.

This work was done at the **Microplasmic Corp.**, *17 Esquire Drive, Peabody, MA 01960. For more information, contact Jerry Patel, president, who along with Dr. Nannaji Saka is the author of this brief; (978) 531-9145; fax: (978) 531-3671; E-mail: microplasmic@juno.com; www.microplasmic.com.*

Acoustic Sensor to Monitor Physiology and Voice

Embedded within an aqueous-couplant gel, the sensor is placed in contact with the torso, head, or throat.

Army Research Laboratory, Adelphi, Maryland

The Army Research Laboratory (ARL) has developed a new method of measuring human physiological stress parameters. This consists of an acoustic sensor positioned inside a fluid-filled bladder in contact with the body. Packaging the sensor in this manner minimizes outside environmental interferences, and signals within the body are transmitted to the bladder with minimal losses. This fluid-coupling technology comfortably conforms to the human body, and enhances the signal-to-noise ratio (SNR) of human physiology to that of ambient noise. An acoustic sensor system can detect changes in a person's physiological status resulting from exertion or injuries such as trauma, penetrating wound, hypothermia, dehydration, heat stress and many other conditions or illnesses. A sensor contacting the torso, head, or throat region picks up the wearer's voice very well through the flesh, with fidelity sufficient to be used as a hands-free voice activation mechanism. Several different sensor configurations developed for evaluation include torso mount, neck attachment, and standard PASGT helmet headband mount.

Potential technology transfer applications in the civilian realm include clinical surveillance in convalescent and Veterans' Administration residences, medical transports, hospitals, and telemedicine. Fire, rescue, and police personnel may benefit from hands-free voice communications with embedded health and performance monitoring. Drivers of vehicles and aircraft could also be monitored.

The data in Figure 1 includes a spoken count from one to ten, and then mouth breathing for the remainder of the data set. Naturally, the heartbeat is present in the low-frequency region. Note, in both the time-waveform and the spectrogram of this figure, the high SNR of voice compared to the "physiological ambient noise" that includes heartbeats and breaths. This, combined with the sensor's inherent noise immunity, could make this sensor location ideal for monitoring voice for voice-stress analysis and communications, in addition to physiology.

The detection of physiology and voice is very important for medical evaluation during evacuation, vehicle/aircraft operator monitoring, or voice commands in a high-noise environment, such as a tactical operations center with multiple speakers. The ability of body-coupled sensors to detect physiology and reduce background noise was investigated, with preliminary

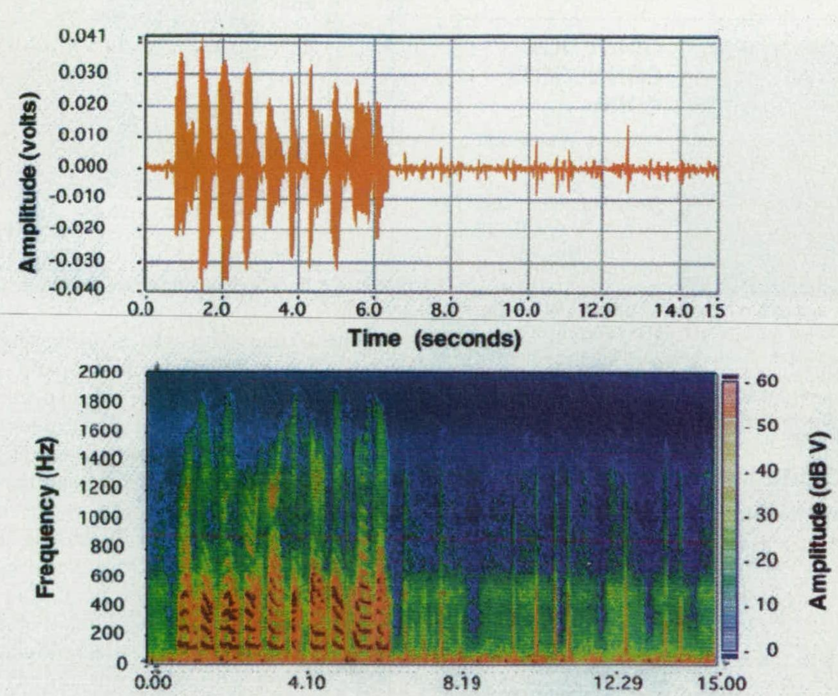


Figure 1. **Fluid Sensor** held at throat for one to ten voice count and mouth breaths.

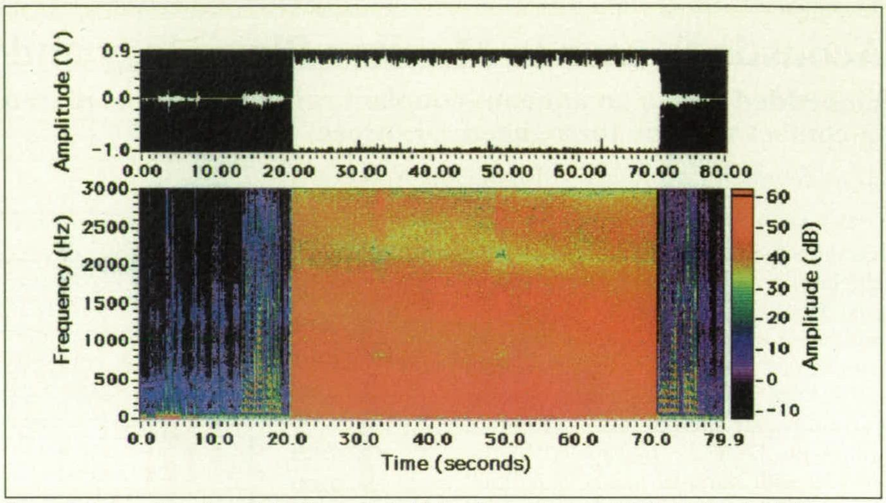


Figure 2. **Boom-microphone** detecting voice in high-noise environment (105 dB, C-weighted).

results as seen here. An acoustic sensor embedded within aqueous-couplant gel was attached to one side of a speaker's neck. Positioned in front of the person's mouth was a boom-microphone configuration. Figures 2 and 3 show simultaneously collected breath and voice data before, during, and after a speaking subject is submerged in a C-weighted noise field of 105 dB (referenced to 20 micropascals, measured in front of the throat) inside an acoustic anechoic chamber (hearing protection was required).

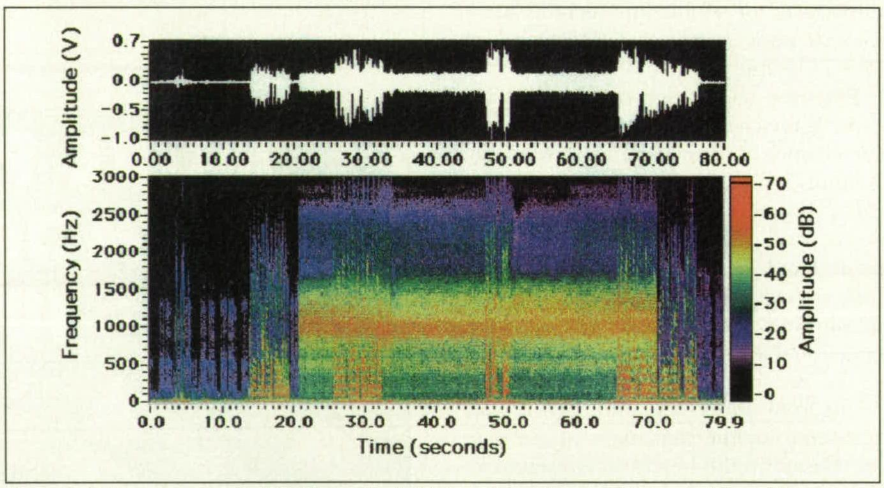


Figure 3. **Gel sensor** on neck detecting voice in high-noise environment (same as Figure 2).

The person wearing the sensors repeatedly vocalized a one-to-ten count between the times of 14 and 19 seconds, 25 and 33 sec, 65 and 71 sec, and 71 and 77 sec, and vocalized "105 dB" between 47 and 50 sec.

The boom-microphone in Figure 2 did not detect any voice during the high-amplitude noise between 20 and 71 sec. In Figure 3, however, the counting is clearly visible throughout the loud noise with the body-coupled gel sensor. Playing the data collect through headsets, the listener could clearly hear and understand the spoken words from the gel sensor, but not the boom-microphone.

Acoustic sensors provide a low-cost, lightweight, noninvasive, and adaptable means to monitor many aspects of a soldier's health and activity. Unlike most medical sensor technologies that look at only one physiological variable, a single acoustic sensor can collect information related to the function of the heart, lungs, and digestive tract, or it can detect changes in voice or sleep patterns, other activities, and mobility. Software algorithms that evaluate data from acoustic sensors can be continuously modified to monitor new parameters, to monitor the correlation between different body functions, or even to understand the interrelations between the soldier's physiology, the task at hand, and the surrounding environment.

This work was done at the **Army Research Laboratory**, *which has received three U.S. patents relating to the technology (No. 5,515,865, No. 5,684,460, and No. 5,853,005). For further information, please contact Ms. Norma Cammarata, ARL's Technology Transfer Officer, at 2800 Powder Mill Rd., AMSRL-CS-TT, Adelphi, MD 20783-1197; (301) 394-2952; fax: (301) 394-5818; e-mail: norma@arl.mil; or the Technical Liaison, Michael V. Scanlon, the author of this brief; (301) 394-3081; e-mail: mscanlon@arl.mil.*

Improved Control of Charging Current for Ni/H Battery

Charging current would be tapered off at the onset of overcharge to limit heating.

etb POWER SOURCES

NASA's Jet Propulsion Laboratory, Pasadena, California

In a proposed method of controlling the electric current supplied for charging a nickel/hydrogen battery, the rate of evolution of heat would be taken into account along with the electrical quantities (voltage, current, and/or charge as functions of time) that are traditionally taken into account. This method might also prove useful for controlling charging currents in batteries based on different chemistries.

The parameters related to limitations on the lifetime of an Ni/H battery are depth of discharge, temperature, and overcharge. The major proximate cause of failure is gradual swelling of plates, associated with overcharge and with the generation of oxygen in the overcharge reaction sustained over thousands of charge/discharge cycles. In principle, the lifetime could be prolonged by minimizing overheating and precisely limiting the amount of overcharge.

The rate of heating cannot be measured directly but can be estimated from other quantities that can be measured. Because an Ni/H cell is a pressure vessel, its internal pressure can be used as an indication of the amount of hydrogen present and thus of the state of charge. Assuming that (1) the void volume in the battery remains constant; (2) the pressure, temperature, and number of moles of hydrogen are related by the ideal gas law; and (3) the charging efficiency is 100 percent, then the rate of increase of pressure during charging should be proportional to the rate of charging; that is, to the charging current.

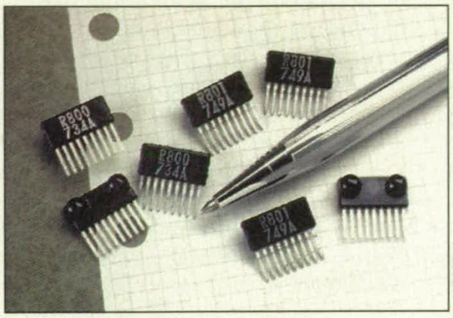
Any deviation from this proportionality would be attributed to a decrease in efficiency associated with the overcharge reactions. The portion of applied current diverted to the overcharge reaction would not be available for the main charging reaction that generates hydrogen; as a consequence, for a given charging current and temperature, the rate of increase of pressure would decrease as the battery went into overcharge. The oxygen generated in part of the overcharge reaction is also quickly recombined in another part of the overcharge reaction; the net effect of the portion of the charging current diverted to the overcharge reaction is to generate heat. Thus, by use of basic equations of thermodynamics, it should be possible to determine the charging efficiency and the rate of generation of heat from measured values of pressure, temperature, and voltage as functions of time.

The proposed method would be implemented in control software. In this method, the rate of generation of heat computed as described above would be used as feedback in a control algorithm that would taper the charging current to maintain the lowest possible battery temperature and minimize the generation of oxygen. The maximum allowable rate of generation of heat would have to depend on the temperature of the battery because charging efficiency decreases with increasing temperature.

This work was done by Paul Timmerman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
NPO-20470

NEW PRODUCTS

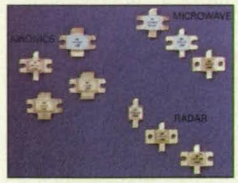
PRODUCT OF THE MONTH



IrDA Wireless Communication Devices

Rohm Corp., Antioch, TN, has added three new models to its RPM800 series of IrDA devices for use in portable equipment such as laptop computers, cellular phones, and advanced digital still cameras. The new products include the RPM-800 CB, the RPM-801CB, and the RPM-851A devices. The company says that these additions make it the first manufacturer to include all components for an IrDA wireless communication function, from the infrared LED to the PIN photodiode and the modulator/demodulator, in a single package. All these new devices support the IrDA version 1.0 SIR (115.2 kbit/s) standard.

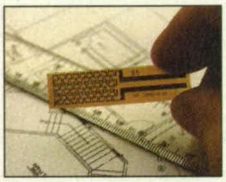
For More Information Circle No. 751



RF-Microwave Silicon Power Transistors

GHz Technology Inc., Santa Clara, CA, has made available the Top of the Line RF-microwave silicon power transistors the company says are designed to meet the requirements of next-generation systems. Numbering ten in all, the line includes four for avionics applications, with power ratings from 350 W to 1 kW and frequencies between 960-1215 MHz; three for weather radars, with power ratings from 35 W to 550 W and frequencies from 650-700 MHz to 1550-1600 MHz; and three for broadband microwave amplifiers with power out from 25-60 W and frequencies from 1350-2470 MHz.

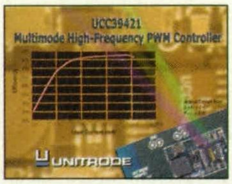
For More Information Circle No. 752



Heat Flux Sensor

RdF Corp., Hudson, NH, calls its Model 27160 the first practical heat flux sensor priced low enough for OEM use. Priced under $20 in OEM quantities, the Model 27160 is based on the principle of a differential thermopile. According to the company, it self-generates an interchangeable, linear mV measurement of heat flow in or out by all modes, convection, conduction, or radiation. It features low thermal impedance, high sensitivity, and fast response. It will measure temperatures from -300 to +300 °F. RdF says that applications include HVAC, medical, structural analysis, equipment protection, and safety.

For More Information Circle No. 755



High-Frequency PWM Controllers

New from Unitrode Corp., Merrimack, NH, is the UCC39421/2 family of multimode high-frequency pulse width modulation controllers, optimized for low-power portable applications. With operation down to 1.8 V input, the UCC39421 can drive either external p-channel or n-channel MOSFETs. All converter topologies can be configured to operate at fixed frequencies as high as 2 MHz. The UCC39422 features all of the same power conversion features, while also providing a programmable power-on reset function and an uncommitted comparator for low-voltage detection.

For More Information Circle No. 758

Capacitor-Charging Power Supplies

The CCS12 series of high-voltage switching power supplies from Maxwell Energy Products Inc., San Diego, CA, offers 12 kJ/s output power capability in a 19-in. air-cooled rack chassis. The series consists of 12 different voltage models, from 1-kV to 65-kV output. Able to be employed in both rep-rate and single-shot systems, the CCS12 incorporates an advanced construction technique, according to the company, that offers the user increased reliability and serviceability. Input power requirements range from 208 VAC 3-ph and 400 VAC 3-ph to 480 VAC 3-ph.

For More Information Circle No. 759

Low-Resistivity CVD Silicon Carbide

Morton Advanced Materials, Woburn, MA, is making available low-resistivity-grade CVD silicon carbide components for semiconductor manufacturing. The company recommends the material for wafer-handling equipment that requires RF coupling, such as in plasma etch, CVD, and MOCVD. The solid ceramic has purity of >99.9995 percent and can be fabricated into components up to 700 mm × 700 mm × 20 mm, and into custom tubes and liners. It can be used where high temperatures (>1500 °C) are required. Morton says the material is the premier choice for RTP/epi rings and susceptors and plasma-etch chamber components.

For More Information Circle No. 760

Process Monitor with Low Loop Drop

The DMS-40LCD-4/20S from Datel Inc., Mansfield, MA, is a miniature 4-20-mA loop powered 4-½-digit LCD readout process monitor with what the company calls impressively low loop drop. Typically 2.9 V, the loop drop makes the device suited for use in process-monitoring current loops incorporating two or more series-connected loop devices. Datel says the device's low loop burden and typical input impedance of 145 ohms allow it to be used in applications employing loop power supplies as low as +8 VDC.

For More Information Circle No. 761

Vol. 23, No. 10 October 1999 This form expires: March 31, 2000

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Physical Sciences

Mathematical Modeling of Two-Phase Flow With Evaporation

Behaviors of evaporating liquid drops entrained in turbulent gas flows are simulated numerically.

NASA's Jet Propulsion Laboratory, Pasadena, California

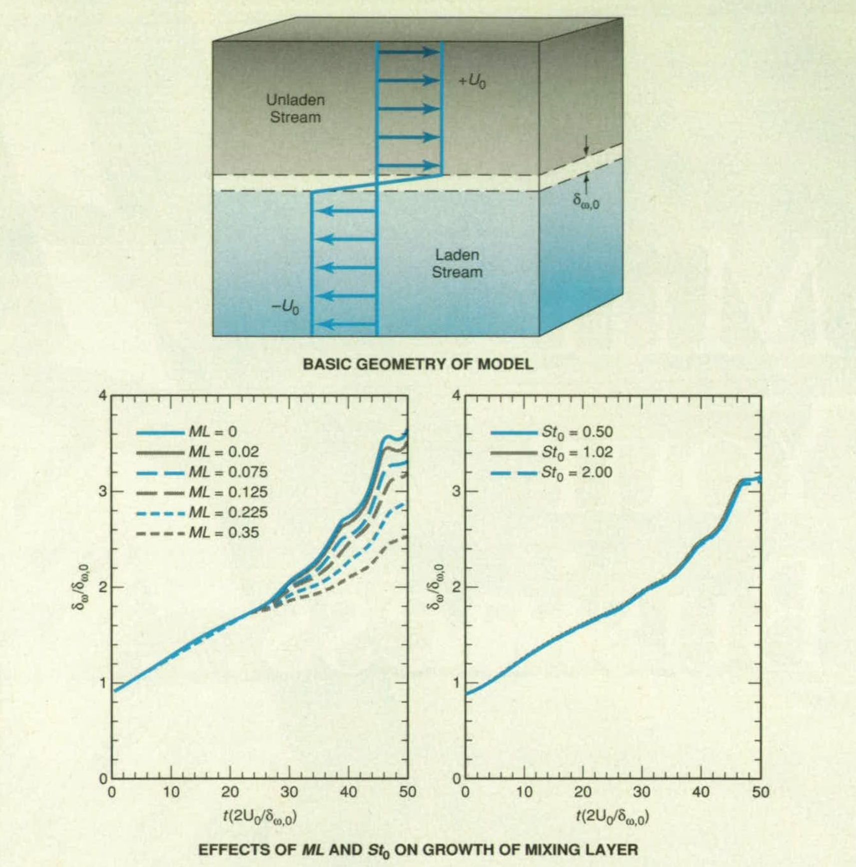
A mathematical model constructed within a theoretical framework applicable to direct numerical simulation (DNS) predicts the behavior of evaporating liquid drops entrained in a turbulent shear layer.

In the model, liquid drops are assumed to be dispersed at low volume fraction (though not necessarily low mass fraction) in a carrier gas. All chemical species are assumed to be calorically perfect. Gravitation is neglected. It is assumed that values of the viscosity, thermal conductivity, and species diffusivity of the gas phase can be prescribed, independently of the local mixture fraction.

The compressible conservation equations for mass, momentum, and energy for the gas phase are formulated in an Eulerian reference frame and include terms to account for exchanges of mass, momentum, and energy with the drops. The drops are assumed spherical and their internal temperature is assumed uniform.

Each drop is tracked in a time-accurate manner in a Lagrangian reference frame; these equations include terms for the drag exerted on each drop by the surrounding flowing gas. Each drop is assumed to exchange heat with the gas phase through convection and conduction only, since this study is performed at low temperature. Evaporation is represented by the nonequilibrium Langmuir-Knudsen law. The model accounts for complete two-way phase coupling (both gas-to-liquid and liquid-to-gas) of mass, momentum, and energy based on a thermodynamically self-consistent specification of vapor enthalpy, internal energy, and latent heat of vaporization.

The model has been used to simulate the behavior of a three-dimensional, temporally developing, initially isothermal gas mixing layer formed by the merging of an airstream with a gas stream laden with hydrocarbon drops. Effects of the initial liquid-mass-loading ratio (*ML*), the initial Stokes number (St_0), the initial temperature of the drops, and the three-dimensionality of the flow on the evolution of the mixing layer were examined. The dominant parameter affecting the flow was found to be *ML* (for example, see figure). The laden stream was found to become saturated before evaporation was complete, at



The **Growth of the Mixing Layer** was found to be increasingly attenuated with increasing ML in the range $0 \leq ML \leq 0.35$, but not appreciably affected by changes in St_0. On these plots, U_0 denotes the magnitude of each of the opposing free-stream velocities, t denotes time, $\delta_{\omega,0}$ represents a specified initial value of vorticity thickness, and δ_ω represents the vorticity thickness at any given time.

all but the smallest values of ML. Drops in the mixing layer were observed to be centrifuged out of regions of high vorticity and to migrate toward regions of high strain in the flow, with resultant formation of concentration streaks in spanwise braid regions wrapped around peripheries of secondary streamwise vortices. Persistent regions of positive and negative slip velocity and slip temperature were identified. Other characteristics examined included variances of liquid- and gas-phase velocities and relationships among gas-velocity, drop-number-density, and thermodynamic profiles. From considerations of first and second order statistics, a comprehensive picture of the mixing layer is described.

This work was done by Josette Bellan and Richard S. Miller of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. NPO-20434*

Temperature-Stable Magnetic Sector for Mass Spectrometer

A temperature-sensitive magnetic shunt would compensate for a temperature-sensitive magnet.

NASA's Jet Propulsion Laboratory, Pasadena, California

A magnetic sector in a proposed miniature mass spectrometer would include (1) a permanent magnet made of a high-energy-product material, (2) a conventional ferromagnetic yoke, and (3) a small temperature-compensating magnetic shunt. In the absence of the temperature compensation, it would be necessary to restrict the operation of the miniature mass spectrometer to a controlled-temperature environment. With the temperature compensation, the instrument could be used to perform chemical analyses in a variety of laboratory, indus-

trial, and field environments over a wide range of temperatures.

The basic physical principle of a magnetic sector for a mass spectrometer dictates that mass of the permanent magnet be inversely proportional to the energy product of the permanent-magnet material. Therefore, a high-energy-product material is a key ingredient for miniaturization. The permanent-magnet material chosen for the proposed magnetic sector is an Nd/B/Fe alloy with an energy product of 45 to 50 MG·Oe (3.6 to 4.0 kJ/m^3). The aluminum/nickel/cobalt alloy (alnico V) previously used in mass spectrometers has an energy density of 5 to 6 MG·Oe (0.4 to 0.5 kJ/m^3). Thus, the use of the Nd/B/Fe alloy would enable a substantial reduction in the size of the permanent magnet.

Unfortunately, the Nd/B/Fe alloy has a negative temperature coefficient of remanent flux density, and this coefficient is greater than that of alnico V and of another commonly used permanent-magnet alloy (see table). In the absence of temperature compensation, this would be problematic: The variation, with temperature, of the flux density in the magnet gap of the mass spectrometer would alter the mass calibration of the instrument. Thus, it would be necessary to perform frequent mass calibrations during operation. Alternatively, it would be necessary to maintain the instrument at constant temperature during operation; the means to do this would add to the size, weight, and power consumption of the instrument.

Alloy	Temperature Coefficient of Remanent Flux Density, percent / °C
Alnico V	−0.02
Sm/Co	−0.04
Nb/B/Fe	−0.10

The **Temperature Coefficient of Remanent Flux Density** of the Nd/B/Fe alloy exceeds the corresponding coefficients of other permanent-magnet alloys.

With respect to the magnetic circuit through the magnet, yoke, and gap, the magnetic shunt could be connected in parallel with either the permanent magnet or the gap. The shunt would be made of an Ni/Fe or Ni/Cr/Fe ferromagnetic alloy with a negative temperature coefficient of permeability. Thus, as the flux density of the permanent magnet decreased with increasing temperature (thereby tending to decrease the flux density in the gap), the reluctance of the shunt would increase (thereby tending to decrease the flux through the shunt and increase the flux through the gap). In other words, the needed effect would be to decrease the variation, with temperature, of the flux density in the gap. By suitable choice of the dimensions of the shunt, it should be possible to reduce the magnitude of the temperature coefficient of flux density in the gap to as little as 0.01 percent/°C over the temperature range from −40 to +20 °C.

This work was done by Mahadeva P. Sinha of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-20332, volume and number of this NASA Tech Briefs *issue, and the page number.*

Books & Reports

Strategies for Optimal Placement of Sensors and Actuators

A paper presents a survey of sensor- and actuator-placement problems from various applications that involve a wide range of engineering disciplines. "Smart" structures that contain sensors (*e.g.,* microphones or strain sensors) and actuators (*e.g.,* loudspeakers or piezoelectric actuators) can be used, for example, to control the shapes of airfoils or to suppress noise or structural vibrations. In designing a "smart" structure, one faces the problem of placing limited numbers of sensors and actuators to maximize some measure of performance; typically, the locations must be selected from a large set of candidate locations.

This work was done by Sharon L. Padula of **Langley Research Center** *and Rex K. Kincaid of the College of William and Mary. To obtain a copy of the paper, "Optimization Strategies for Sensor and Actuator Placement," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category. L-17839*

Computational Test Cases for a Rectangular Supercritical Wing

A report describes wind-tunnel experiments on a rectangular supercritical wing and presents test cases that have been selected from the archived sets of experimental data for comparison with computational fluid dynamics (CFD) predictions. In the experiments, the wing was driven in pitching oscillations at frequencies below the lowest natural vibration frequency of the wing. The data obtained in the experiments included the static pressures and the in-phase and quadrature components (with phases referenced to the pitching motion) of unsteady pressures at a number of points on the upper and lower wing surfaces.

This work was done by Robert M. Bennett and Charlotte E. Walker of **Langley Research Center.** *To obtain a copy of the report, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category. L-17830*

Evolvable Multiagent Approach to Spacecraft Communication

A paper presents the concept of a system for autonomous communication among multiple satellites and other spacecraft. The design of the system would be based on an evolvable architecture of multiple intelligent agents (that is, artificial-intelligence constructs implemented in software and hardware) that would com-municate and cooperate with each other in performing such tasks as enabling each spacecraft to track the others, analyzing communication links, dynamically making and breaking links, and otherwise generally allocating communication resources. The paper discusses some of the problems to be addressed in constructing the system, describes an example of an evolvable system containing knowledge-based agents, and describes some hardware modules that could be used in building the system.

This work was done by Sanda Mandutianu of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the paper, "An Evolvable Multi-Agent Approach to Satellite Communication Systems," ac-cess the Technical Support Package (TSP)* ***free on-line atwww.nasatech.com*** *under the Electronic Components and Systems category. NPO-20432*

Configuration Management of Software for Designing HSCT4.0

A report discusses the development of a highly complex system of distributed-computing, multidisciplinary design-optimization software, called "CJOpt," for use in research on model 4 of the High-Speed Civil Transport (HSCT) airplane (HSCT4.0). The emphasis in the report is on the application of formal software configuration management (SCM) to ensure the integrity of, and the traceability of changes in, the optimization software.

This work was done by James C. Townsend, Andrea O. Salas, and M. Patricia Schuler of **Langley Research Center.** *To obtain a copy of the report, "Configuration Management of an Optimization Application in a Research Environment," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category. L-17868*

Update on SiC Fiber/[$MoSi_2$-Matrix/Si_3N_4 Particle] Composites

A report presents updated information on the developments described in "$MoSi_2$-Based Composite Materials for Aircraft Engines" (LEW-16617), *NASA Tech Briefs*, Vol. 22, No. 9 (September 1998), page 62. To recapitulate: Hybrid composites of (1) SiC-based fibers within (2) matrices that are, themselves, composites of $MoSi_2$ containing 30 to 50 volume percent of Si_3N_4 particles are candidate high-temperature-resistant materials for use in advanced aircraft engines. The addition of the Si_3N_4 particles (1) results in the formation of an Si_2ON_2 protective scale that increases resistance to low-temperature accelerated oxidation, which otherwise causes catastrophic "pest failure" of $MoSi_2$; (2) increases high-temperature creep strength to almost 105 times that of neat $MoSi_2$; (3) doubles room-temperature toughness; and (4) decreases the coefficient of thermal expansion to such an extent as to eliminate matrix cracking in the presence of SiC-based fiber reinforcement, even after thermal cycling.

This work was done by Mohan G. Hebsur of Ohio Aerospace Institute for **Glenn Research Center**. *To obtain a copy of the report, "Development and Characterization of SiC/$MoSi_2$-$Si_3N_4(p)$ Hybrid Composites," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16884.

Modifications of the Ventricular Assist Device

A report discusses some modifications of the ventricular assist device (VAD), which was described in "Small Implantable Pump Would Assist Circulation of Blood" (MSC-22424), *NASA Tech Briefs*, Vol. 20, No. 7 (July 1996), page 86. The VAD is a surgically implantable, miniature rotary pump designed to assist in pulmonary or systemic circulation of blood. The modifications, guided by computational simulations of blood flow in the pump, were directed partly toward reducing stagnant flow, backflow, and unsteady flow in order to reduce shear stresses and thereby reduce damage to blood cells and thereby, further, reduce clotting.

This work was done by Bernard J. Rosenbaum of **Johnson Space Center**, *Dochan Kwak of Ames Research Center, Robert J. Benkowski of the Baylor College of Medicine, and Kris Cetin of MCAT Institute. To obtain a copy of the report, "Ventricular Assist Device," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-4871. Refer to MSC-22822.

EPRI of Distributions of Free Radicals in Polyimide Samples

A report describes experiments in which electron paramagnetic resonance imaging (EPRI) was used to determine one-dimensional spatial distributions of free radicals in two plate specimens of PMR-15 polyimide. One specimen had been postcured at a temperature of 315 °C in nitrogen, then thermally cycled 300 times between room temperature and 335 °C in air; the other specimen had been post-cured at 316 °C in air, then further postcured at 371°C in nitrogen, but not thermally cycled. EPRI of the thermally cycled specimen showed a higher concentration of free radicals in the surface layers than in the bulk.

This work was done by Mary Ann B. Meador of **Glenn Research Center**, *Myong K. Ahn of Indiana State University, and Sandra S. Eaton and Gareth R. Eaton of the University of Denver. To obtain a copy of the report, "Electron Paramagnetic Resonance Imaging of the Spatial Distribution of Free Radicals in PMR-15 Polyimide Resins," access the Technical Support Package (TSP)* ***free on-line at www.nasa tech.com*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16821.

The Pressure Belt: A Smart Sensor Network System

A project team made up of engineers from The Boeing Co. and Endevco Corp. — with research funding provided by the Defense Advanced Research Projects Agency (DARPA) — has developed a state-of-the-art MEMS-based (MicroElectroMechanical System) belt to measure pressure at multiple points on the skin of aircraft. The measurements, along with other parameters, are used to compute the Coefficient of Pressure (CP) in order to determine the aircraft's structural loads during flight conditions.

The Pressure Belt consists of multiple smart sensor modules mounted on a thin polymeric tape. The modules are configured in a multi-drop bus topology communicating to a Transducer Bus Controller (TBC) through a full duplex serial digital bus operating at 2.5 MB per second. Each smart sensor module contains a MEMS pressure transducer, temperature transducer, and the necessary transducer-to-bus interface circuitry (Transducer Bus Interface Module —TBIM) that includes signal conditioners, data acquisition, data signal processing, and digital bus for bi-directional communication.

For all of these functions to fit on a 25 × 25 × 2.5 mm silicon substrate, it was necessary to develop an analog and a digital Application Specific Integrated Circuit (ASIC), and to use Multi-Chip Module (MCM) technology packaging. A unique coating compound was used to protect the TBIMs and achieve reliability without hermeticity. The flexible polymeric tape contains copper traces for the transducer digital bus, power, and ground lines.

The Present Technology

Current flight load test technology includes an array of plastic tubes that transfer pressure from a desired measuring point on the aircraft's skin to the electronic instrumentation system located inside the airplane. The plastic tubes are susceptible to frequent obstruction from water and foreign particles, and introduce an inherent time delay between the actual pressure point on the aircraft's skin and the measurement system located in the instrumentation bay. It is composed basically of a pressure scanner (various pressure points are multiplexed pneumatically into a single pressure transducer), an analog signal conditioner unit, and a data acquisition unit. Digital data from the data acquisition unit is sent to a computer for storage and post-processing tasks.

To perform a flight load test on a Boeing 737, approximately 800 channels of instrumentation and eight months cycle time are required to design, fabricate, and install the measuring system. Numerous access holes must be drilled on the airplane structure in order to route the significant bundles of tubes and cables. Drilled holes change the airplane's integrity, requiring structural engineers to study and approve any prospective holes.

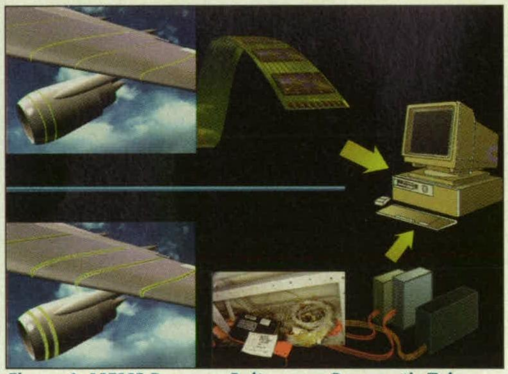


Figure 1: MEMS Pressure Belt versus Pneumatic Tubes

The New Pressure Belt

The new Pressure Belt is built in segments containing up to six smart sensors or TBIMs and one Power Conditioner/Buffer Module. The segments are connected to each other through a low-profile connect in no specific order, and are treated as Line Replaceable Units (LRUs) from the logistics, test, and calibration viewpoints. As many as 255 smart sensors or TBIMs may be connected. Each module is protected by a specially developed coating compound instead of a metal enclosure in order to provide the needed environmental protection and to satisfy the 2.5-mm-high design goal.

Each smart sensor module, as described in Figure 2, has a MEMS silicon pressure/temperature transducer and two signal conditioner and data acquisition channels, one to process the pressure signals and the other to process temperature signals. Pressure data is corrected digitally in real time for ZMO (zero measurand output) and linearity inaccuracies over the temperature range. Digital data out of the A/D converters is processed through three real-time hardware engines: a digital, low-pass filter with a programmable corner frequency; a multinomial correction algorithm to compensate for temperature inaccuracies and to express the corrected data in SI engineering units; and the bus interface control engine. Temperature correction coefficients and a Universal Unique Identification Code (UUID) are stored in non-volatile memory as part of the Transducer Electronic Data Sheet (TEDS).

The A/D is 12-bit with a variable sampling rate from 20 to 100,000 samples per second. Its sampling rate is programmed by downloading coefficients to the decimating digital filter (DDF). The sampling rate is proportional to the bus clock. Traditional data acquisition systems require changes in the anti-aliasing filter corner to accomplish different sample rates.

The TBIMs use a DDF and a fixed A/D converter sampling rate (102.4k samples per second) to generate lower output data rates. The DDF first will perform some digital anti-aliasing filtering and then discard samples to obtain lower output sample rates.

Communication is accomplished through two full-duplex, bi-directional RS-485 buses. A high-speed bus transmits measured data, and a low-speed bus transfers configuration and status data. This feature allows the TBC to acquire measured data at full speed from some TBIMs while, at the same time, being able to configure other TBIMs through the low-speed bus without any bus contention. The TBC provides 10V power and a 5-MHz clock to achieve synchronous data sampling between all of the TBIMs on the bus.

The analog signal conditioner, which is part of an ASIC, is capable of interfac-

ing to different types of transducers: piezoelectric; piezoelectric with internal electronics; piezoresistive; and strain gauges with voltage or current excitation, variable capacitance accelerometers, AC voltage, and DC voltage.

The TBC provides power and the master clock to synchronize all smart transducers. It also contains enough memory storage to retain data collected from all smart transducers connected to the bus if it is unable to transfer it in real time to the host computer. The TBC also contains a real-time clock to time-tag the data acquired under the trigger command sent by the TBC. The Pressure Belt design follows very closely the work done by the IEEE/NIST 1451.3 committee.

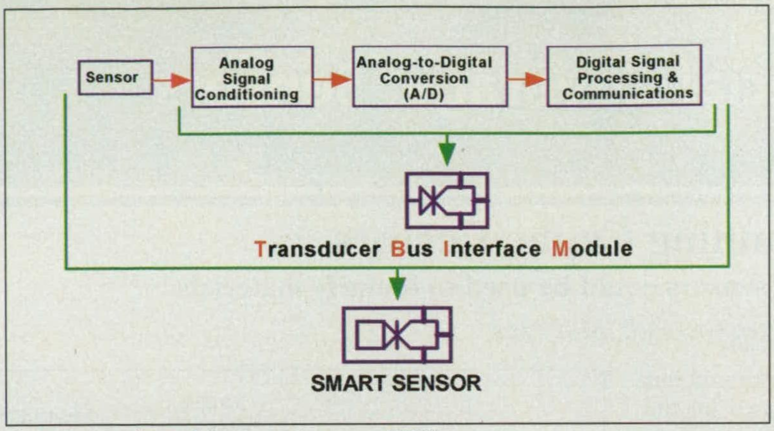


Figure 2: Functions of the Smart Sensor and TBIM

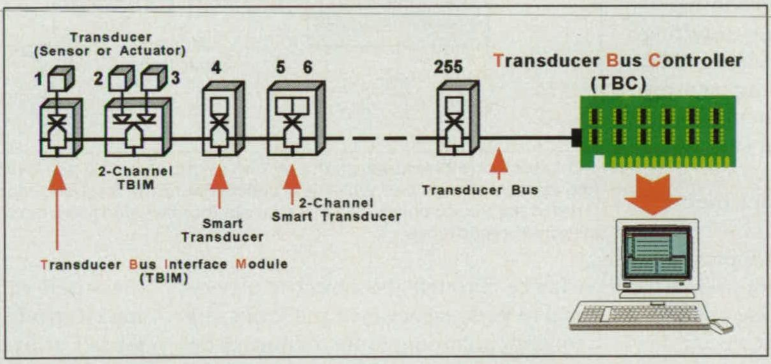


Figure 3: Smart Sensor Network

An important capability of the TBC is to assign automatically a bus ID to each TBIM or smart transducer. New smart transducers that are connecting to an already active bus will not interfere with bus operations until they are assigned a bus ID by the TBC. Automatic self-identification eliminates the possibility of multiple smart transducers with the same bus ID that can be caused by human error. The operator does not have to pre-program the bus address before connecting a TBIM to the bus. The TBC is able to initiate smart transducer diagnostics and self-test, an important function that provides the operator with a higher level of confidence that a given measurement channel is alive and working properly.

Silicon Transducer

The MEMS silicon sensor used for the Pressure Belt is a modified version of the Endevco Model 8515C, which has been used for many years in flight load testing. The sensor is a silicon micromachined pressure diaphragm designed for a 0-15 psia operational range. It incorporates a fully active Wheatstone bridge strain sensing circuit on the diaphragm. Ion implantation is used to apply the strain gauge circuit to the diaphragm. The sensor measures $1.55 \times 1.19 \times 0.41$ mm.

The vacuum chamber of this absolute reference sensor is accomplished with a second silicon support attached to the back of the diaphragm. The support is hermetically glass-sealed to the sensor and has a cavity that is evacuated during the sealing process. This cavity always presents the stable reference vacuum to the back side of the diaphragm.

While the diaphragm currently in use is a standard part, the reference support has been designed specifically to allow flip chip mounting of the MEMS assembly to the silicon MCM using solder bumps or conductive epoxy. This maintains the lowest possible profile since no wires extend above the top of the MEMS device that is only 0.41-mm thick. The special flip chip support incorporates feedthrough holes so that electrical connections can be made at the physical mounting surface. The feedthrough holes consist of etched holes through the reference support. Gold is then deposited, which creates electrical pads on the surface of the support, and connects them to the pads on the surface of the diaphragm at the bottom of the feedthrough holes. Temperature is determined by measuring the voltage across the pressure transducer that is excited with a constant current source.

The new MEMS Pressure Belt system is expected to reduce the flight test preparation cycle time from eight months to two months. It would eliminate the need for drilled access holes, improve measurement accuracy from 1.5% to 0.1% of reading throughout its temperature range, and eliminate time delays and clogging problems. It also would improve reliability by having the measurement system integrated with the sensor in one very small package, and by being able to perform test and identification of each smart sensor module through computer commands from the TBC.

Pressure Belt Status

Prototype Pressure Belt units were tested in a laboratory environment to compare the performance of the Pressure Belt with the existing pressure tube analog system. The test results for the Pressure Belt units demonstrated excellent correlation with the expected output in a calibrated environment. The same prototype Pressure Belt units also were installed on a B737 airplane, and flown to verify the operation of the TBIM circuitry in the flight environment. Once again, the results for the Pressure Belt demonstrated good correlation with the output of a corresponding pressure tube analog system and were less susceptible to factors that degrade the quality of the signal.

The first Pressure Belt segments are expected to be produced by the end of this year. Testing of the units will be performed in the first quarter of 2000. The smart sensor technologies developed for the Pressure Belt are being incorporated into other packaging configurations for various test and monitoring applications.

Significant cost savings can be realized by providing a common communication interface between existing analog transducers and the digital network bus using the TBIM. By applying these same designs to other applications, the difficulties associated with traditional measurement systems can be minimized or eliminated using smart sensor network systems.

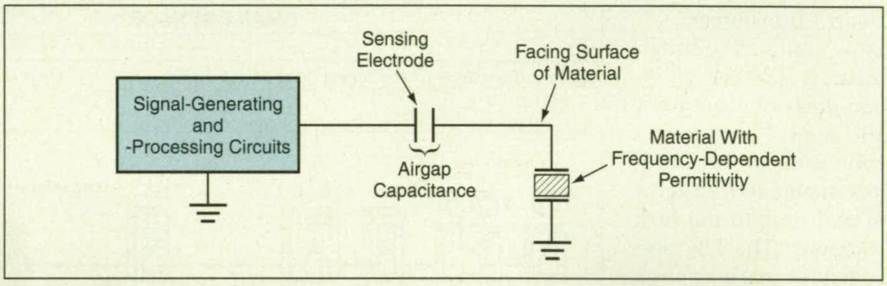
For more information, contact the authors of this article, Alex Karolys (alex@endevco.com) and Bruce Swanson (bruce@endevco.com), at Endevco Corp., 30700 Rancho Viejo Rd., San Juan Capistrano, CA 92675; Tel: 800-982-6732 or 949-493-8181; www.endevco.com

Frequency-Scanning Capaciflectors

Capacitive proximity sensors could be used to identify materials.

Goddard Space Flight Center, Greenbelt, Maryland

Capacitive proximity sensors of this proposed type would be based on the capaciflector concept, with an extension of hardware and software designs to incorporate capabilities for scanning in frequency and analyzing the resulting capacitance-vs.-frequency data. The proposed frequency-scanning sensors would perform all the functions and offer all of the advantages of capaciflectors; in addition, they would provide information on materials within their capacitive-sensing ranges.



The **Capacitance Measured** via the sensing electrode can be approximated as a series combination of two capacitances, one of which is proportional to the frequency-dependent permittivity of the material of the sensed object. The material can thus be identified from the frequency dependence of the measured capacitance.

Capaciflectors and related topics have been described in a number of prior articles in *NASA Tech Briefs* during the past several years. A typical capaciflector includes a sensing electrode and a driven shielding electrode, both excited at the same voltage, frequency, and phase via voltage followers. The voltage follower that drives the sensing electrode also includes an operational-amplifier circuit for measuring the sensing-electrode current, which includes a component proportional to the excitation voltage and to the capacitance between the sensing electrode and any objects in the vicinity.

The figure illustrates the basic measurement principle of a frequency-scanning capaciflector. In the case of a nearby dielectric object, the sensed capacitance can be regarded as two capacitances in series: an airgap capacitance between the sensing electrode and the facing surface of the object, and a capacitance between the facing surface of the object and electrical ground. The dc values of these capacitances depend partly on the geometry of the electrode and the object. The ac capacitance through the object is proportional to its dc capacitance and varies with frequency according to the frequency dependence of the permittivity of the object material. Thus, it is possible to use the shape of the measured capacitance-vs.-frequency curve to differentiate between the effect of geometry and the effect of the object material, and to distinguish among materials with different permittivity-vs.-frequency curves.

A computer could store data on capaciflector responses as functions of frequency for sensed objects made of a variety of known materials. Then the computer could compare data from a capaciflector frequency scan with the stored data by use of a mean-square estimator with the amplitude of the frequency response as a free variable:

$$\min_{a,m}\Sigma(ar_{f,m} - c_f)^2,$$

where a is the unknown amplitude, $r_{f,m}$ is the stored frequency response of the mth material at frequency f, and c_f is the measured capaciflector response (sensing-electrode current or proportional signal) at frequency f. That is, the computer could choose a combination of amplitude and material to minimize the mean squared error between the measured response c_f and the stored response $r_{f,m}$.

Some applications for this sensor include rapid determination of rock types, determining the type of snow and ice accumulation on aircraft wings, and determining if passengers are carrying weapons or explosives.

This work was done by Charles E. Campbell, Jr., of **Goddard Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category.*

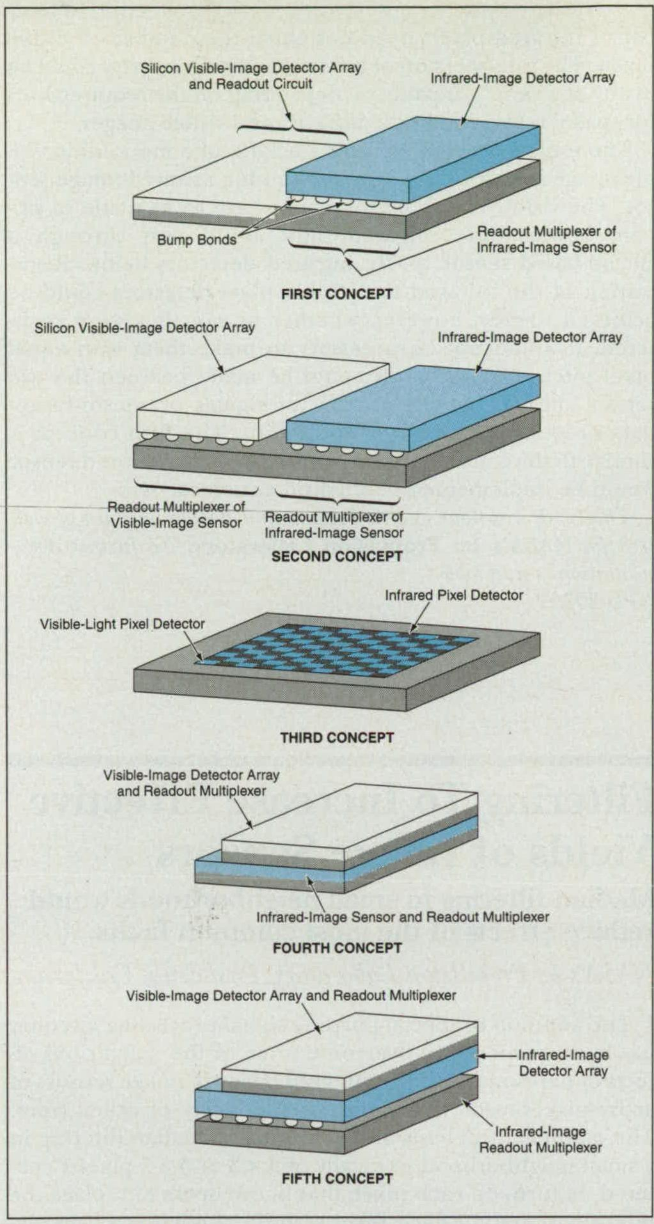
This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-13618.

Integrated Infrared- and Visible-Image Sensors

It would not be necessary to split optical paths.

NASA's Jet Propulsion Laboratory, Pasadena, California

Integrated circuits capable of sensing both infrared and visible images have been proposed. Until now, the usual practice for simultaneous imaging at both infrared and visible wavelengths in the same camera has involved splitting of the optical path into an infrared and a visible branch, each containing a separate image sensor optimized for its wavelength range. In contrast, each of the proposed image sensors would include pixel detectors for both wavelength ranges, and sensors could be designed to operate with or without splitting of optical paths.



Infrared- and Visible-Image Sensors would be integrated. Pixel detectors could be arranged in side-by-side subimages or else interspersed or superimposed in the same image area.

The figure illustrates five alternative design concepts for the proposed image sensors. In the first and second concepts, the infrared- and visible-light pixel detectors would be segregated into adjacent subimage areas, necessitating splitting of the optical path. The first concept calls for enlargement of the silicon integrated-circuit multiplexer chip of a traditional infrared image sensor to accommodate a visible-light image sensor on the additional area. The second concept is similar to the first one, except that the visible-light detectors would be implemented in a hybrid structure. The visible-readout portion of the multiplexer circuitry could be similar to the infrared-readout portion, or it could be designed as a photoelectron-counting circuit.

The third, fourth, and fifth concepts do not entail splitting of the optical path. According to the third concept, the visible and infrared pixel detectors would be interspersed throughout the same image area. The visible-image detectors could be of the complementary metal oxide/semiconductor (CMOS) active-pixel-sensor (APS) type. The infrared detectors could be of the thermopile or bolometer type. CMOS readout circuitry would be used for both sensors. The num-

ber of infrared pixels need not equal the number of visible pixels. The interspersion of infrared and visible pixels could be in any of a variety of patterns, depending on the requirements for spatial resolution in the infrared and visible images.

The fourth concept calls for stacking of a monolithic visible-image sensor on top of a monolithic infrared-image sensor. The visible-image sensor would have to be made of silicon, because the infrared light could pass through a silicon-based sensor to the infrared detectors below. Registration of the infrared and visible pixel detectors could be achieved readily; however, whether or not they were registered, it would not be necessary to make them with equal pixel pitches. Wire bonds could be made between the two sensor chips to enable sharing of signals or sensor-fusion data processing on one or both chips. The fifth concept is similar to the fourth concept, except that the infrared sensor would be implemented in a hybrid structure.

This work was done by Eric Fossum and Bedabrata Pain of Caltech for **NASA's Jet Propulsion Laboratory.** *No further documentation is available.*
NPO-20209

Filtering To Increase Effective Yields of Image Sensors

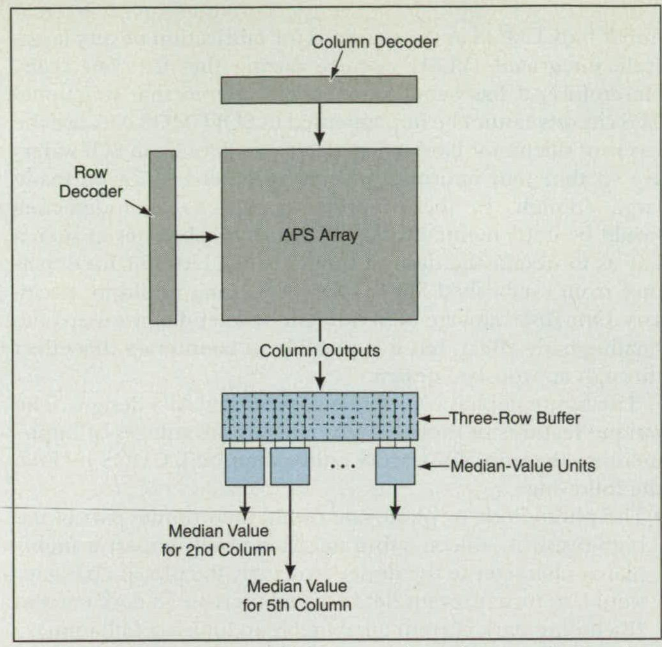
Median filtering in small neighborhoods would reduce effects of the most common faults.

NASA's Jet Propulsion Laboratory, Pasadena, California

The addition of special-purpose signal-processing circuitry has been proposed to overcome some of the deleterious effects of hardware faults in integrated-circuit image sensors of active-pixel-sensor (APS) type and possibly of other types. The mathematical basis of the method is median filtering in a small neighborhood (typically of 3 × 3 or 5 × 5 pixels) centered, in turn, on each pixel; that is, one seeks to replace the intensity signal for each pixel with the median-intensity signal for its neighborhood. From the perspective of a human observer viewing the image on a remote video display, such median filtering would reduce or eliminate the visible effects of malfunctioning single pixels or of malfunctioning rows or columns of single-pixel width — the faults most commonly observed in large state-of-the-art integrated-circuit image sensors. Thus, the effective production yields of the image sensors would be enhanced.

Heretofore, neighborhood median filtering has usually been implemented by software in the first stage of processing of digitized pixel signals. In the proposed method, the median filtering would be implemented in hardware; more specifically, by use of additional electronic circuitry that would be installed on the periphery of the image-sensor area. In comparison with the software implementation, the proposed hardware implementation would offer the advantage of reduced computational burden and possibly greater processing speed.

The figure shows a simplified layout for implementing median filtering in 3 × 3 neighborhoods. The intensity signals from pixels would be read out row by row and initially stored in a three-row buffer. Each cycle of operation would begin with reading signals from a new row into the buffer, accompanied by dropping the signals from the oldest row from the



Median-Intensity Values would be stored in a three-row buffer, then found for pixels in adjacent 3 × 3 neighborhoods along the middle row in the buffer. A three-phase cycle, with incrementing of the column locations by one step in each phase, would be necessary to obtain all the median values for the row in question.

buffer. Units containing analog circuits with timed, transistor-switched, access to adjacent 3 × 3 neighborhoods in the buffer would then identify and pass on the median intensity signals from these neighborhoods. These units would operate on each group of three rows in three phases as follows:

During the first phase, the units would put out the median values associated with the middle row in the buffer and with the columns in the numerical sequence 2, 5, 8, and so forth. In the third phase, columns in question would be those in the numerical order 3, 6, 9, and so forth. In the third phase, the columns in question would be those in the numerical order 4, 7, 10, and so forth. Upon completion of the third phase, all available median values for the middle row in the buffer would have been generated. Then a new cycle would begin with loading of a new row into the buffer and with the row loaded on the previous cycle becoming the new middle row.

This work was done by Orly Yadid-Pecht, Barmuk Mansoorian, and Bedabrata Pain of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
NPO-20211

Active-Pixel-Sensor ICs With Photosites in Substrates

Heretofore, SOI CMOS has been considered unsuitable for APS circuits.

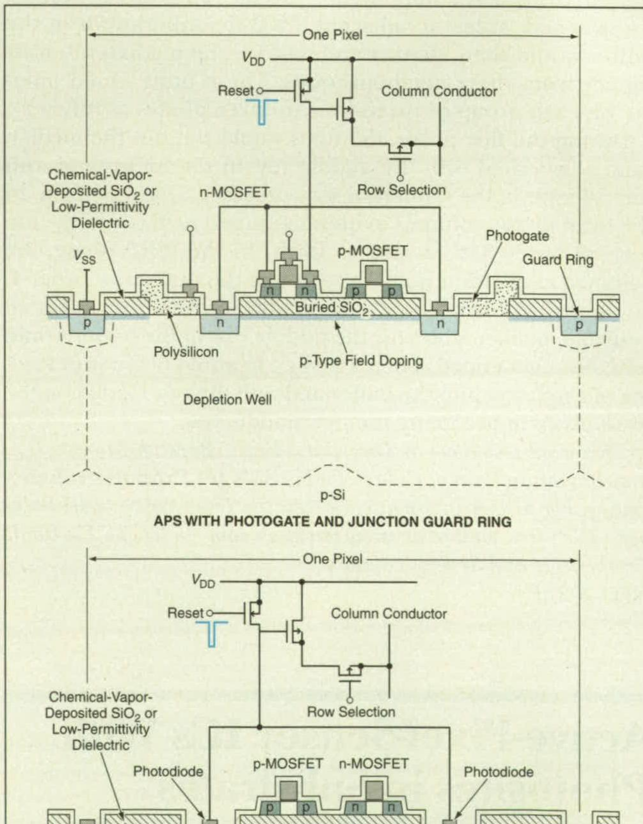
NASA's Jet Propulsion Laboratory, Pasadena, California

Focal-plane arrays of active-pixel sensors (photodetectors integrated with in-pixel readout transistors) would be designed and fabricated within the emerging technological discipline of silicon-on-insulator (SOI) complementary metal oxide/semiconductor (CMOS) integrated circuits (ICs), according to a proposal. SOI CMOS seems destined to supplant the more fa-

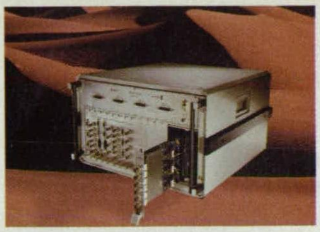
miliar bulk CMOS as the standard for fabrication of very-large-scale integrated (VLSI) circuits, during the next few years. Heretofore, it has been generally considered that functional APS circuits cannot be implemented in SOI CMOS because the layers of silicon for fabricating electronic devices on SOI wafers are so thin that optical absorbing volumes cannot be made large enough. In the proposed approach, photodetectors would be implemented within SOI silicon substrates in such a way as to obtain the desired functionality. Little or no departure from established SOI CMOS processing would be necessary. One disadvantage of SOI might be a tendency toward the floating-body effect, but it is possible to counteract this effect through appropriate design.

The figure depicts two of several proposed APS designs. The unique features of these designs and the advantages of implementing them in SOI CMOS rather than bulk CMOS include the following:

- The photodiode or photogate would incorporate part of the high-resistivity silicon substrate. This would impart a highly planar character to the device structure; the planar character would, in turn, prevent field-assisted increase in dark current (including dark current attributable to ionizing radiation).
- The high resistivity of the substrate would make for a large depletion width, with consequent high quantum efficiency and thus high optical collection efficiency.
- Because the size of the photosite would be much larger than the minimum under design rules, the photosite could



These **Cross Sections** (not to scale) represent unit cells of two of several APS designs proposed to be implemented in SOI CMOS.



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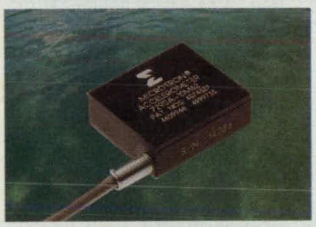

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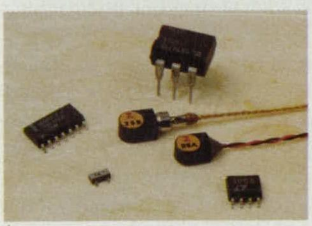

MODEL 25A/B
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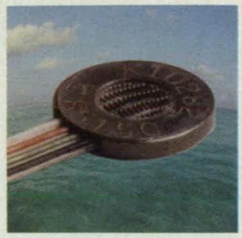

MODEL 8515C
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This rugged, miniature, high sensitivity piezoresistive pressure sensor is available in 0-15 and 0-50 psia pressure ranges and has a 200 mV full-scale output. Its extremely low 0.030 inch profile and small 0.25 inch diameter package makes it ideally suited for use in small-scale model tests, wind tests as well as in flight tests on aerodynamic surfaces.
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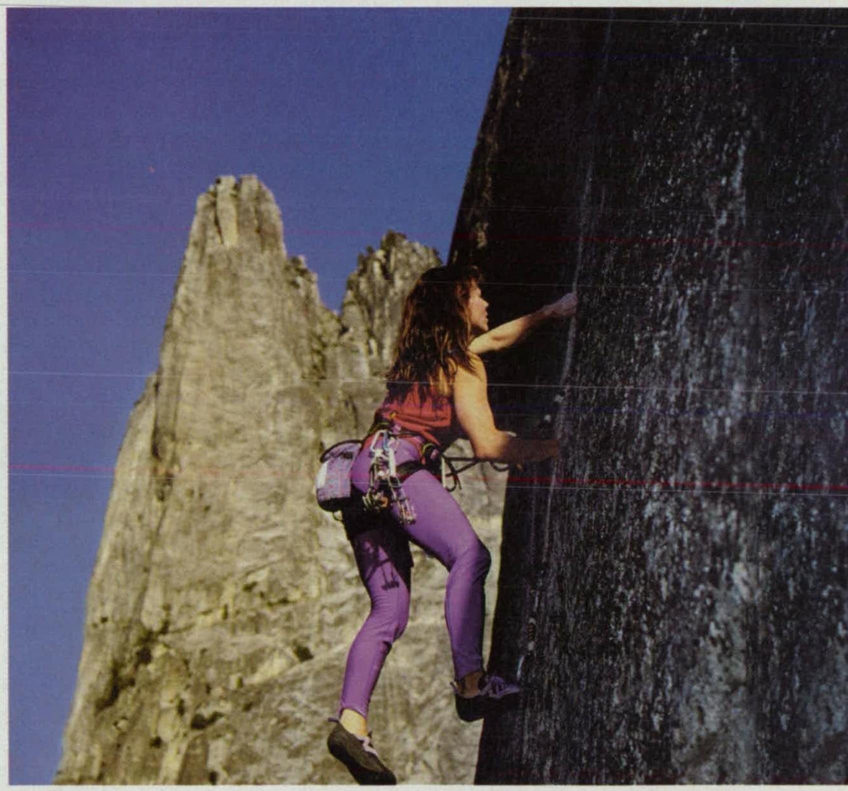

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For More Information Circle No. 555

be fabricated along with other substructures by standard SOI fabrication techniques.

- The capacitance of the sensing node would be lower because the substrate capacitance would be lower. Lower sensing-node capacitance would translate to higher conversion gain and lower noise, and thus the ability to detect light at lower levels.
- Complementary transistors would be placed in each pixel to obtain high dynamic range. A metal oxide semiconductor field-effect-transistor with p doping (p-MOSFET) would be incorporated for use as a reset gate that would enable reset all the way to the power-supply voltage (VDD). It is not possible to incorporate such a structure into an APS in bulk CMOS without adversely affecting the pixel size and increasing the potential for latch-up, but it is possible in SOI CMOS because SOI transistors are formed in isolated islands.
- Cross-talk would be reduced because parasitic capacitances would be lower and because of the isolation of individual transistors.
- In the absence of substrate coupling, timing patterns could be changed to enable the simultaneous operation of analog and digital subcircuits. The change in timing patterns would enable operation at higher speeds.
- Photodetectors, in-pixel circuitry, and peripheral circuitry would all exhibit greater radiation hardness because silicon layers would be thinner and because of the prevention of field-assisted increase in dark current mentioned above. Furthermore, the isolation of transistors would afford immunity to latch-up.

This work was done by Bedabrata Pain of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

NPO-20534

Sensor Webs

Notable features would include flexibility of deployment, low power consumption, and low cost.

NASA's Jet Propulsion Laboratory, Pasadena, California

Sensor webs are developmental collections of sensor pods that could be scattered over land or water areas or other regions of interest to gather data on spatial and temporal patterns of relatively slowly changing physical, chemical, or biological phenomena in those regions. Each sensor pod would be a node in a data-gathering/data-communication network that would span a region of interest. Each sensor pod would contain two modules: (1) a transducer module that would interact with the environment to gather the desired data and (2) a communication module.

The basic concept of a network of sensors is not new. The novelty of the sensor-web concept lies in exploitation of a confluence of advances in integrated circuits for radio communication, wireless-network communication technology, and cheap micromachined sensors. This exploitation takes the form of a design concept that affords flexibility of configuration and operation of networks while minimizing power consumption.

A sensor web would contain a few primary nodes and many secondary nodes. Data would be transferred from node to node within the network. The primary nodes would have the additional capability and task of communicating signals into and out of the sensor web: For example, at a primary node, sensory data gathered by the web could be transmitted to an overhead aircraft or satellite or to a local field computer.

Inasmuch as the power needed for intraweb transfer of data increases with the bandwidth of the sensor signals, the sensor output signals should be of low bandwidth to make it possible to minimize power consumption in the sensor pods. Fortunately, many natural phenomena that one might wish to monitor (*e.g.*, temperature or concentrations of chemicals) are inherently of low bandwidth. In cases of phenomena that vary more rapidly, it could be necessary to compress the sensor data at the nodes before transmission.

The use of intraweb, node-to-node communication would reduce the power needed to transmit data out of a web. It would also make it possible to reduce the energy consumed by power-hungry sensors: Web nodes could query each other to track the movements of microclimatic or other fronts over the web, so that power-hungry sensors could be activated only when a front is known to be passing. In other words, intraweb communication enables a nonlinear increase in the value of the local data collected in much the same way that an aggregate of neurons exhibits more intelligence than does a single neuron. Moreover, the synergistic interaction among many separate node transducers would increase the value of the collected data by providing instantaneous correlation across the web.

A sensor web would not be inherently restricted to contain a specific number of nodes or to operate within a predefined area. The primary nodes could be located anywhere in the network, and multiple webs deployed in a given area would naturally mesh with one another. A sensor web could be regarded as instrument, the surveying area of which could be expanded by multiple deployments of nodes.

A sensor web would be a relatively cheap instrument because sensor pods could be mass-produced, taking advantage of economies of scale. Because of this cheapness, individual sensor pods could be regarded as expendable. As a further consequence, it would be possible to "reseed" a sensor web with fresh nodes to replace ones that have failed; thus, the sensor web could be repeatedly renewed, enabling it to operate for an indefinitely long time.

A sensor web could be made as redundant and/or as dense as desired by simply distributing as many nodes as desired over a given survey area. Redundancy would, of course, render the sensor web tolerant to failures of individual pods. High density could be utilized to achieve high spatial resolution and/or to obtain statistically significant numbers of data when surveying biological or other phenomena that are inherently stochastic.

Sensor webs could be useful in almost any endeavor in which there is a need for low-power, low-bandwidth, long-term monitoring over large areas. For example, they could be used to monitor microclimates and concentrations of nutrients for agricultural purposes, to track flows of toxins in ground water, to monitor traffic, or to monitor seismicity in a survey area.

This work was done by Kevin Delin, Shannon Jackson, and Raphael Some of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

NPO-20616

October 1999

Motion Control Tech Briefs

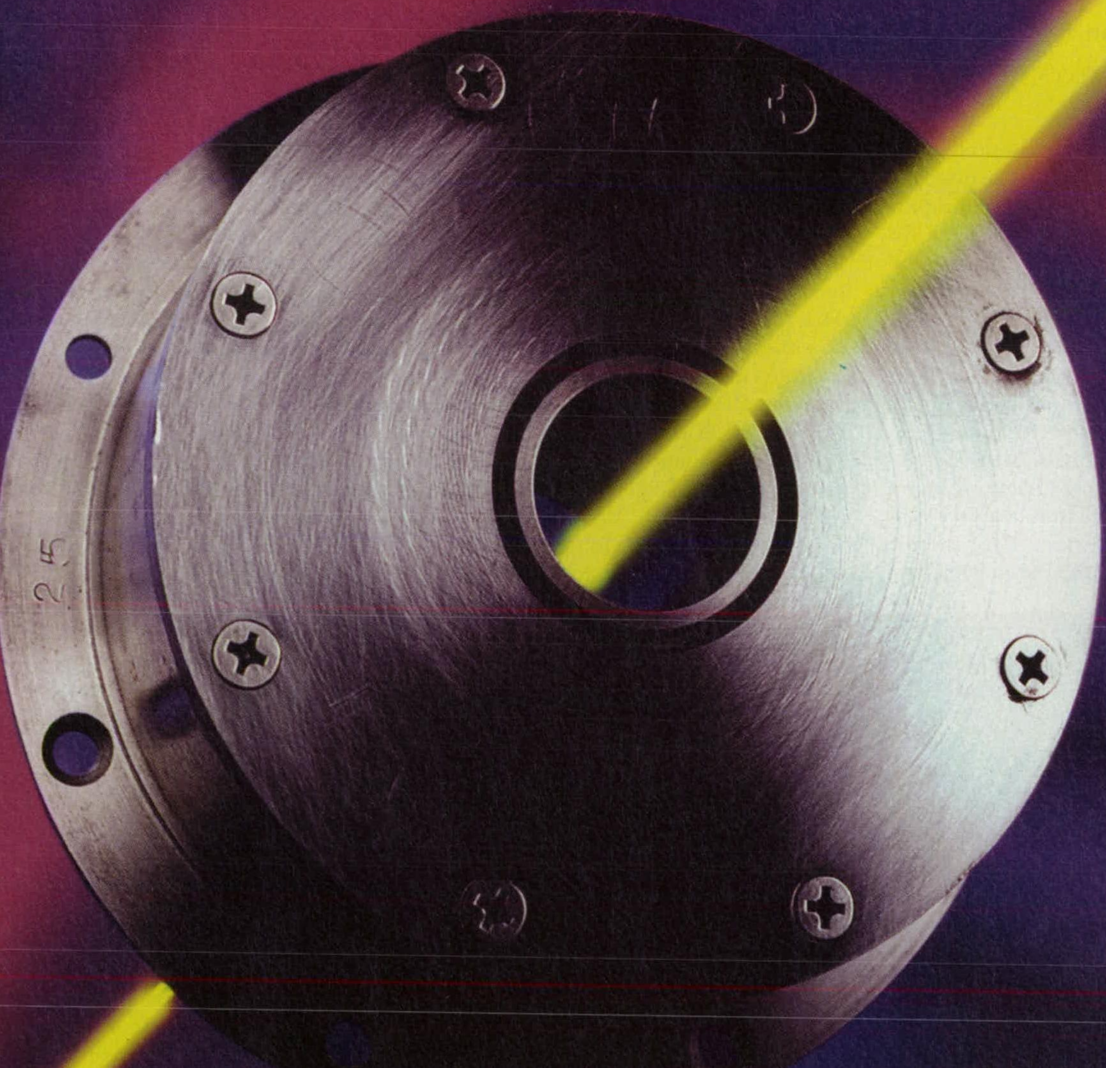


Photo courtesy of Empire Magnetics Corp. See New Products.

A Small Ball Slide with a Big Impact

A tiny Del-Tron ball slide assembly cuts costs and improves accuracy in the testing of printed circuit boards.

A very small ball slide assembly helps make possible the testing of printed-circuit boards (PCBs) without building the custom test devices called clamshell fixtures. The result is that PCB manufacturers have a faster and less expensive option for testing low-volume boards.

The ball slide provides z-axis motion for a test probe known as a moving probe tester (MPT) from Probot Inc. of Branford, CT, a privately held company that produces a family of MPT systems capable of handling a variety of board sizes. The systems include user-friendly Windows-based software. Because the C-1 ball slide assembly from Del-Tron Precision Inc. of Bethel, CT, has an extremely low mass, Probot could move the probes fast enough to make the MPT method practical, also keeping momentum low enough to create minimal witness marks, which result from contact. The small size of the C-1 also made it possible for the MPT's two probes to operate close to each other, a factor that is growing increasingly important as the grid size on PCBs is reduced.

For PCB manufacturers, the high cost and long lead time involved in building clamshell test fixtures is a major drawback on low-volume jobs, especially quick-turn-around prototypes. It can take up to 100 person-hours to build the fixtures required to test such boards on a bed-of-nails tester. Typical cost to build such a fixture is about $500 for materials and processing, plus $0.25 per test point. For a double-sided surface mount technology (SMT) multilayer board with 6000 test points, for example, the cost would run somewhere in the neighborhood of $2000. Fine-pitch boards with feature sizes of 25 mils (635 µm) or less and double-sided SMT boards are particularly difficult to fixture. In many cases, building the fixture exceeded the production cost of the board.

Probot's MPT technology eliminates the need for custom test fixtures by using moving probes to travel to the appropriate test points on a PCB.

Probot Inc.'s MPT technology uses moving probes to travel to the appropriate test points on a PCB. The test can be generated from CAD/Gerber or net list data in about 30 minutes. It takes longer than a bed-of-nails test to run because, rather than having one probe per test point, the MPT uses a total of just two that must travel to each point. Advances in the last few years, however, have improved test speed by a factor of 10.

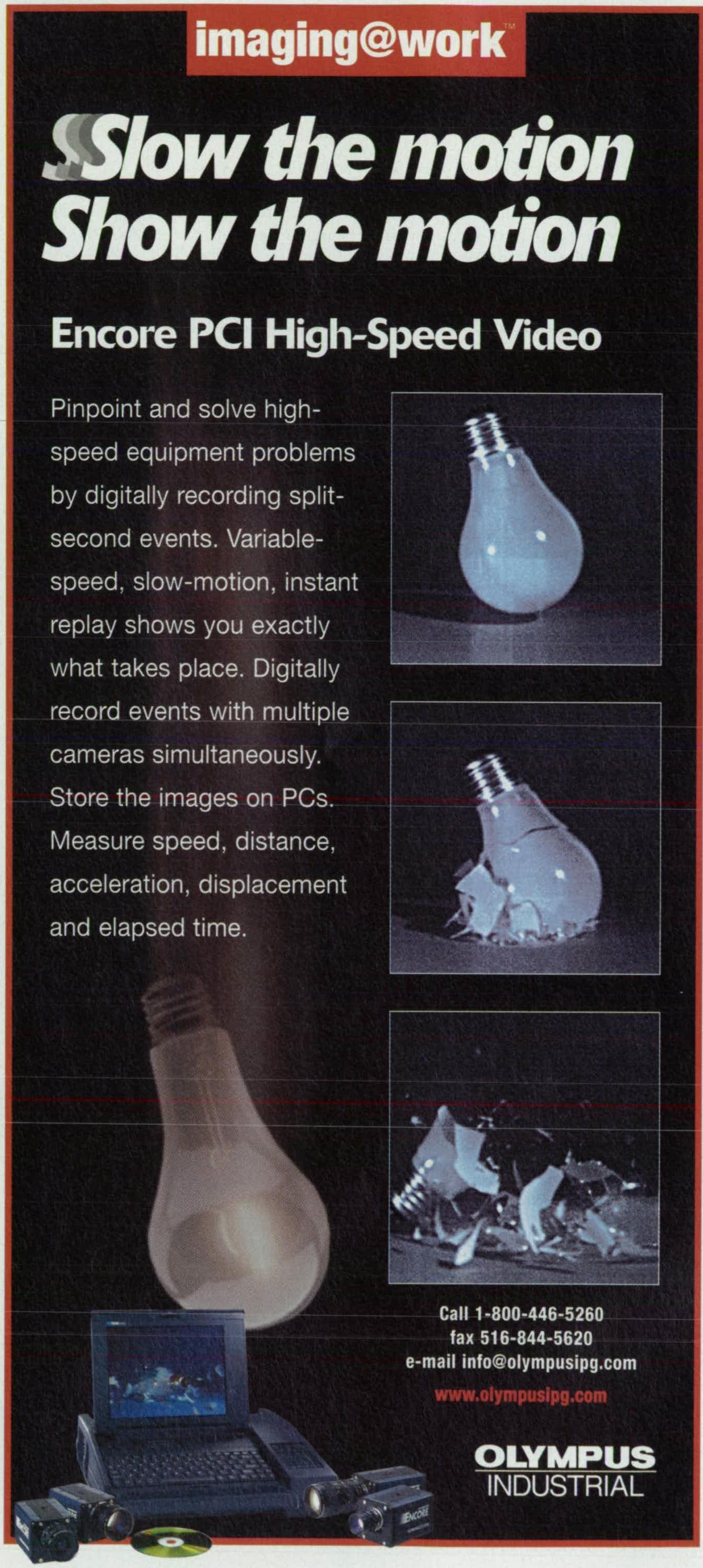
A key advantage of MPT testers is their ability to test even very dense fine-line SMT and multichip module (MCM) products without the pin slips that are commonly experienced with bed-of-nails testers: there are no pins, so there cannot be any pin slips. Therefore the accuracy of the test results is far better with an MPT than with the bed-of-nails test. While the actual test time on an MPT is slower than on fixtured testers, the total cycle time for small runs is much less, because there is no fixture-building time, and the retest or verification time is zero.

In designing the MPT, Probot was particularly concerned with the motion of the test probes in the z axis, which brings them into contact with the PCB. Boards are frequently warped, so the z-axis position of the probe will vary across the board. When the probe makes contact, it must leave as small a witness mark as possible. A witness mark is a function of the momentum with which the probes hit the solder pad, which in turn is a function of the mass of the ball slide times its velocity.

The challenge Probot faced was getting enough velocity to make this test method a good alternative to custom clamshell fixtures. Because the latter have one probe for every test point, and only have to close once, they can close slowly to ensure minimal witness marks. The probes on the MPT, on the other hand, must touch each test point, so they must operate fast enough to make this approach feasible, yet without so much momentum that the probes damage the pads or leave too great a witness mark.

Another consideration in the design of the MPT was the ability to bring the two probes close together. Although this was not a great challenge when Probot started building such systems 12 years ago, it has grown in importance with the increasingly tight grid spacing on PCBs. These days, the probes must come within 0.003 to 0.004 inch of each other when testing to determine whether neighboring nets are causing a short in the net of interest.

After examining a number of different linear motion devices, Probot engineers selected a Del-Tron C-1 ball slide assembly to provide the z-axis motion. With dimensions of 0.75 inch long by 0.23 inch high by 0.38 inch wide, this is the smallest ball slide assembly on the market. Its size and lightweight aluminum carriage translates into the smallest mass of any device available. The small mass reduces momentum



while enabling the probes to move fast enough to contact thousands of test points in a reasonable amount of time. After programming and setup, which take approximately 30 minutes, a board with 6000 test points can be tested in half an hour or less. Even at that speed, however, momentum is low enough that witness marks are minimal.

The C-1's size is related to its extraordinarily low friction. Because it uses linear ball bearings, it has less friction to overcome and can therefore have a low mass. Much more commonly used rotary ball bearings have a higher coefficient of friction because the peripheral track is shorter on the inner race than on the outer race, causing the ball to skid on one or the other. Linear ball bearings run exactly equal distances on the pair of tracks, permitting the balls to run without friction, wear, or skidding at any preload. Steel shafts, ground over the entire length, also reduce the coefficient of friction, which is typically 0.003 for Del-Tron ball slides.

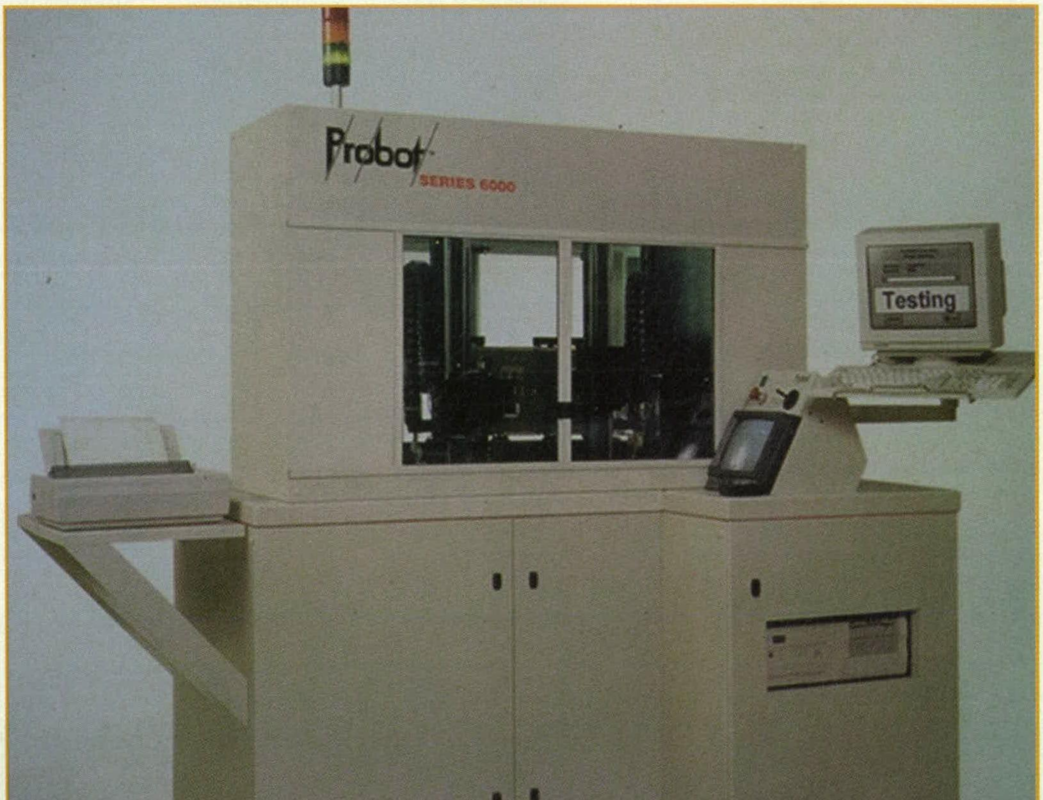
The probes are attached to the C-1 ball slide assembly with two screws that attach to built-in holes to simplify installation. The mounting surfaces of the ball slide are machined flat and smooth, and parallel to each other and the line of motion. They must be mounted on smooth, flat supports that will not deflect under load. When Probot started building MPT systems, there was seemingly a problem with inconsistency in the slides' preload. Since preload is set at the Del-Tron factory, Probot engineers called Del-Tron for help. Del-Tron discovered that the problem stemmed from the fact that the mounting surface on the MPT was not perfectly flat. Since the ball slide assembly is made of aluminum, it was conforming to the MPT machine and losing its adjustment. Once they improved the flatness of the mounting surface, the C-1s performed perfectly.

Del-Tron ball slides are well suited to the MPT application because they require exceptionally low levels of maintenance. They are lightly lubricated during assembly, and are self-cleaning in normal service. Additional lubrication is not required, except for applications involving speeds above 1800 inches/min or continuous high loading. When used at the rated load capacity and moderate speeds, a life of 10 million inches of travel can be expected. The expected life at one-half the rated load is 100 million inches.

The use of an MPT system on low- and medium-volume PCB jobs has helped Spectra, a contract PCB manufacturer based in Clarksburg, MD, reduce production costs on low-volume (1-7 pieces) and very high-tech work (sub 0.016-in. [406-μm] pitch) by an average of 20 percent compared to fixture-only testing. At the time it was purchased, the MPT cost $200,000. The machine operates 24 hours a day, five days a week. Expensing over five years yields a cost of just under $10 per hour. Assuming a $40 hourly rate including labor and overhead, it costs only $80 to test four typical boards. This provides a dramatic savings from the $2000 required to build just one clamshell fixture. By passing these savings on to customers, Spectra has been able to achieve a competitive advantage. Lead time on low-volume jobs has also been significantly improved because the time needed to build a clamshell fixture often exceeded the time needed to build the board.

Although the small C-1 ball slide assembly is not something the user is aware of, its operation plays an important role in the performance of an MPT system. With its extremely low mass, it is the critical component that allows the probes to contact PCBs at high enough speeds to make MPT practical, while keeping momentum low enough to leave only a very small witness mark on the pads.

For more information, contact Ed Keane at Del-Tron Precision, Inc., 5 Trowbridge Drive, Bethel, CT 06801; (203) 778-2727; fax: (203) 778-2721; www.deltron.com.



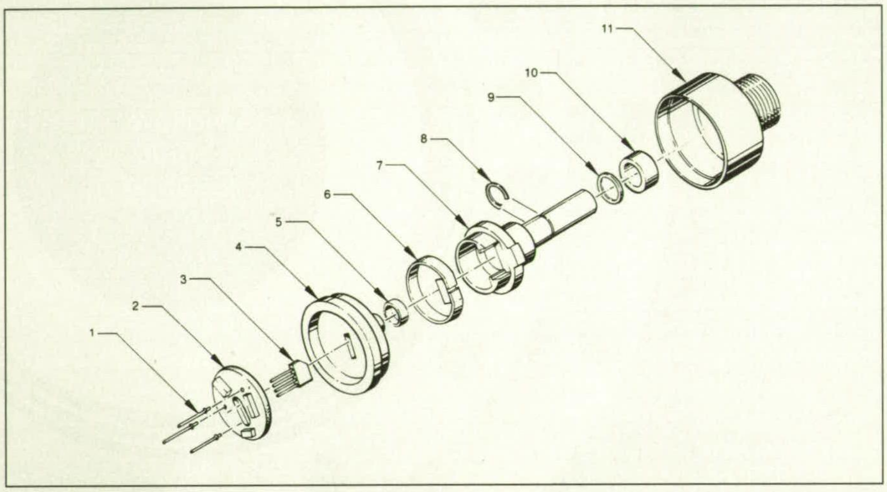
The ball slide from Del-Tron Precision provides z-axis motion of test probes in Probot's moving probe tester (MPT), shown here.

Noncontact Hall-Effect Position Sensor for Harsh Environments

The rotational life of the solid-state sensor exceeds 50 million revolutions.

Spectrol Electronics Corp., Ontario, California

Spectrol has produced an innovative design for a three-terminal voltage output device that integrates a Hall-effect sensor and a patented magnetic circuit to convert radial motion into a voltage-output signal. Standard electrical angles are at 60, 75, 90, 105, 120, 135, and 150 degrees. Standard linearity is ±2 percent with special linearities as low as ±0.25 percent.



The Spectrol Model 155 is a **Noncontacting Position Sensor** that can resolve rotation up to 180 degrees. Key: (1) terminals; (2) printed circuit board; (3) Hall-effect IC chip; (4) carrier; (5) bearing cap; (6) ring with magnet; (7) rotor; (8) C ring (2); (9) shim; (10) sleeve bearing; (11) housing.

Potential motion control applications for the sensor include construction vehicles, industrial controls, marine equipment, and material handling. The sensor can quality for underhood automotive use requiring high accuracy and repeatability. For off-road vehicles, it is especially useful for systems employing steering and throttle control, in-cab levers and pedals, and other applications requiring angular position and feedback.

The sensor is constructed so that a magnet is rotated around a Hall-effect IC at the center of rotation of a standard potentiometer-type housing. The changing magnetic field causes the output of the Hall device to swing from 0.5 to 4.5 V. Standard units require an input voltage of 5 V DC ±10 percent. A second input voltage option is available that allows a 5.5 to 24 V DC unregulated voltage source.

Because it is electrically noncontacting, with all circuitry and components

The **Spectrol Model 155** position sensor.

encapsulated in epoxy, the sensor is immune to water, dirt, dust, lubricants, shock, and vibration, and will operate at 100-percent efficiency while submerged in salt water. The only components susceptible to wear are the shaft and bronze sleeve bushing. Minimum rotational life of the sensor is 50 million cycles with no side load. The bearing system, however, is extremely robust and will withstand substantial side loading while providing millions of revolutions of rotational life. The Hall-effect technology is contained in a package measuring 7/8 in. in diameter and 0.7 in. deep with a -32 threaded bushing. Maximum weight is 1.5 oz. The sensor is EMC-compliant, Class C, 200 V/m to 1 GHz.

Specific applications include leveling and level suspension systems, especially those in oppressive environments; hydraulic actuator and valve positioning and feedback; feedback for angular position sensors; pressure sensing, even under constant dither; and any number of other systems and assemblies that involve radial or linear movement and motion control.

This sensor design was created by the Advanced Development Group at **Spectrol Electronics Corp.**, *4051 Greystone Drive, Ontario, CA 91761, and colleagues from both Spectrol and Wabash Technologies, Inc., of which the former is a unit. For more information contact Brad Canfield at 1-800-624-8902; fax: (909) 923-6765; E-mail: bcanfield@spectrol.com.*

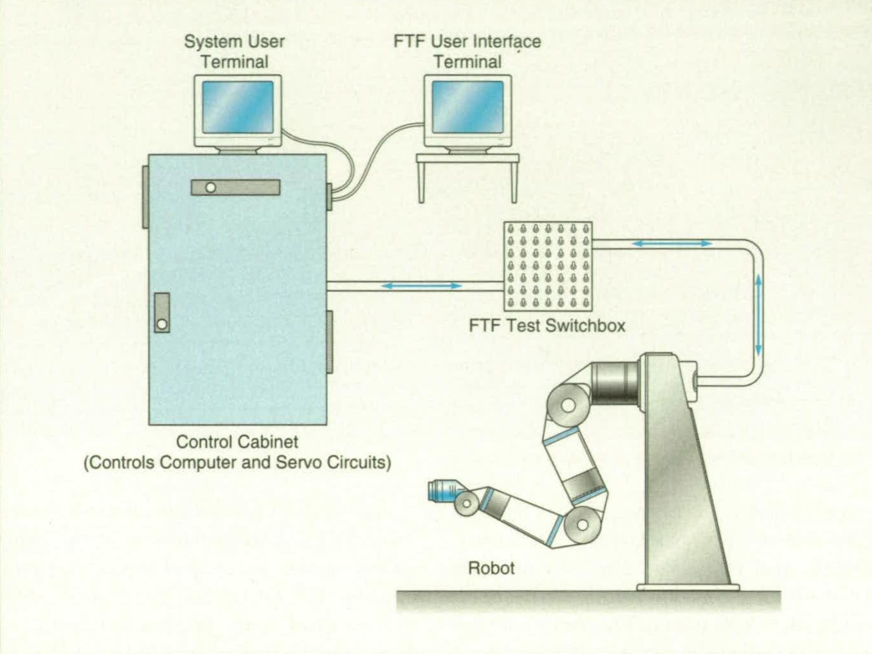
Fault-Tolerant Feedback System for Robot Control

This system takes corrective action when transducers are found to be defective.

Lyndon B. Johnson Space Center, Houston, Texas

A fault-tolerant feedback (FTF) system has been integrated into a robot control system to prevent robot-arm runaways that could be caused by failure of one or more transducers such as joint-position, torque, and motor-temperature sensors, or in associated wiring harness channels. The FTF system responds to a transducer failure by commanding either safety shutdown or else continued operation of the robot in a degraded mode. The FTF system can detect errors in joint-position, velocity, and torque feedback signals far more quickly than older systems can, thereby reducing uncontrolled motion of the robot arm before a shutdown command is executed. The FTF system can help to ensure safe and efficient operation of a robot that must share its workspace with humans and with delicate materials and equipment.

The FTF system is implemented on a single processor circuit board that plugs into the backplane of the robot-control computer and that operates between the motion-controller and servo-processor subsystems of the robot-control system. An analog-to-digital input circuit board and analog buffer/filter circuit board are also used to acquire data. All additional data and control capability required by the FTF system are available through a servo-level interface circuit. The FTF system also includes a user interface that consists of a video display terminal and a keyboard (see figure). (*Continued*)



The **FTF System** is an integral part of the robot-control system. It detects erroneous transducer signals and modifies the control laws accordingly to help ensure safe operation and increase reliability.

The FTF intercepts robot-joint-position commands from the motion controller to the servo processor. It also evaluates feedback information from the servo processor and the input board every 10 milliseconds. By use of a mathematical model of the servo system, the feedback signals are compared to each other to determine whether any transducers have failed.

The comparison of transducer signals occurs after the signals have been processed through second-order Butterworth filters. The filter frequency is selected so that only information below the natural frequency of vibration of the robot-drive mechanism is evaluated. This is essential when motor and axis information are compared and helps to eliminate false error indications caused by noise, nonlinearities, and dynamical error in the mathematical model. The differences between the actual signals and the signals computed from the model are compared to predetermined tolerances specified by the operator. When one of these differences exceeds the applicable tolerance, an error (and thus a transducer failure) is deemed to have occurred, and the FTF responds accordingly.

When no transducer failure has been detected, the FTF passes the commands unchanged to the servo processor. When a transducer failure has been detected as described above, then depending on the current mode of operation, the FTF system either immediately disables the robot or else executes a different control law for the affected coordinate axis, eliminating the use of the faulty transducer. The execution of the different control law is accomplished by use of feedback information from the servo processor, information from the mathematical model of the servo system, and the position command from the motion controller. The FTF system then sends a motor-current command instead of a joint-position command for the affected axis to the servo processor. With respect to the remaining axes, for which transducer failures have not been detected, the control system operates normally.

The FTF system can be made to operate in any of three modes called "safe," "battlefield", and "disabled." In the safe mode, the FTF system immediately disables the robot upon detection of any error. This mode is used when it is crucial that the manipulator not collide with objects in the workspace and provides a great increase in safety over other robotic systems. The battlefield mode provides for continued operation, with some degradation of performance, after a transducer failure. This mode significantly increases the reliability of the robotic system but at the expense of performance and safety. The disabled mode is used for calibration of the FTF system and evaluation of the performance of the rest of the robotic system (that is, with the FTF system excluded).

This work was done by Paul H. Eismann, James P. Karlen, and Talt Blevins of Robotics Research Corp. for **Johnson Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category.*

MSC-22591

Proper Orthogonal Decomposition in Optimal Control of Fluids

Suitably formulated reduced-order mathematical models can be satisfactory approximations for purposes of control.

Langley Research Center, Hampton, Virginia

A methodology proposed for actively controlling flows involves the use of proper orthogonal decomposition (POD) to derive computational models of reduced order. The methodology could be particularly useful for controlling flows of gases and liquids in real time.

The need for reduced-order modeling arises because of the inherent complexity of the computations for solving the full Navier-Stokes equations for the dynamics of fluids. One can reduce the time and cost of computation by use of reduced-order models. The problem is to derive suitable reduced-order models that approximate the essential dynamics well enough for purposes of control. The present POD-based methodology provides a systematic and optimal way to derive reduced-order models of relatively high accuracy while maintaining well-conditioned matrices in a matrix-vector form of the dynamical equations ("system matrices" for short). The methodology may not be effective in all cases and must be applied with care. In those cases in which it is effective, it can provide adequate control performance at significantly reduced computational cost.

The conventional approach to the discretization of the Navier-Stokes equations or other nonlinear partial differential equations by use of a finite-difference, finite-element, spectral method involves the use of basis functions (*e.g.*, trigonometric functions, Legendre polynomials, or piecewise polynomials) that are mathematically convenient but that have very little connection with either the underlying physics of a specific case or the corresponding partial differential equations. In contrast, POD involves the use of basis functions generated from experiments or from numerical solutions of the partial differential equations. More specifically, it involves the extraction of an optimal set of basis functions (perhaps containing only a few basis functions) from a computational or experimental data base, by use of an eigenvalue analysis. Then by means of Galerkin projection, a solution is calculated as a linear combination of basis functions from the optimal set. This solution is the desired reduced-order model solution.

In a test case, the methodology was applied to a two-dimensional flow in a channel that includes a backward-facing step. At high Reynolds numbers, the flow separates and recirculation appears (see figure). The problem was for-

Flow Over a Backward-Facing Step in a two-dimensional channel at a Reynolds number of 1,000 was chosen as a test case. The arrows shown here represent velocity vectors at selected positions. Computational simulations have shown that recirculation (represented by the reversal of arrows) immediately downstream of the step can be reduced by use of optimal blowing control according to the methodology described in the text.

mulated as one of blowing of fluid on part of the step surface to reduce the recirculation and thereby reduce the length of reattachment. Computational simulations with as few as 9 POD modes showed that optimal blowing control could effectively eliminate separation and significantly reduce the size of the recirculation bubble and the reattachment length.

This work was done by S. S. Ravindran of **Langley Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category. L-17846*

Biomorphic Robot With Distributed Power

The major advantages would be simplicity and reliability.

NASA's Jet Propulsion Laboratory, Pasadena, California

The biomorphic robot with distributed power (BIROD) is a prototype of a class of robots that will contain simple, reliable distributed actuators that will consume power from local sources — a design concept inspired in part by biological actuators like muscles in limbs. The BIROD concept stands in contrast to the traditional machine-design concepts of (1) central (therefore vulnerable) sources of power and (2) distribution of power through complex (therefore troublesome) linkages that include gears, pulleys, levers, and other mechanisms. The BIROD concept is potentially applicable not only to robots but also to systems as diverse as home appliances, automobiles, and spacecraft.

At the time of reporting the information for this article, the BIROD had been designed, assembled, and the initial motor movements were demonstrated. The initial design calls for the use of electrical power to actuate muscle wires. (A muscle wire is made of a shape-memory alloy. By sending a sufficient electric current along the wire, one can heat the wire above its transition temperature, causing it to change length. When the current is turned off, the wire cools, returning to its original length.)

With further development, BIROD designs might evolve toward greater degrees of biomorphism. For example, actuators might be made to derive energy from locally stored chemicals that could be recharged; in this aspect, the BIROD chemical/energy cycle would be reminiscent of the adenosine diphosphate/adenosine triphosphate (ADP/ATP) cycle in biological systems. Going even further toward biomorphism, BIRODs might even be made capable of repairing themselves.

This work was done by Kumar Ramohalli of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category. NPO-20606*

Vibratory Accelerometer and Gyroscope

Subtle effects related to vibrational degeneracy and mass imbalance are exploited.

NASA's Jet Propulsion Laboratory, Pasadena, California

A device that measures both translational acceleration and rotation exploits the dynamics of a vibratory structure that resembles a clover leaf. This device is related to other vibratory accelerometers and vibratory gyroscopes in which vibrations in suitably shaped structures are excited electrostatically and measured either capacitively or piezoresistively. The basic principle of this device could

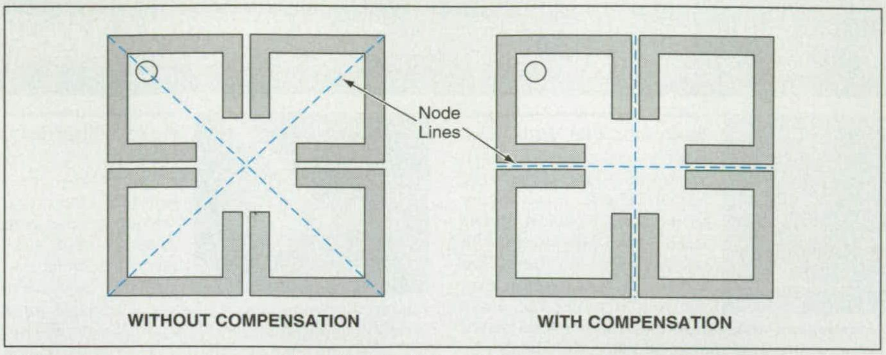
also be applied to a different structure, provided that, like the clover-leaf structure, it vibrates in substantially degenerate modes and provided further that it has a small mass imbalance.

The figure depicts the clover-leaf structure in the present device. This structure vibrates in two degenerate modes. A small mass imbalance defines the shape of the modes in that it causes the node lines of the vibrational pattern to lie along (1) a line that runs through the geometric center of the structure and the location of the mass imbalance and (2) a line perpendicular to the aforementioned line. In the presence of a nominal constant (*e.g.*, zero) rotation or constant translational acceleration, it is possible to rotate the node lines to make them coincide with the Cartesian axes of symmetry of the structure; this is accomplished by applying an electrostatic force of such a magnitude as to contribute a negative spring-stiffness component that compensates for the mass imbalance.

The vibrational dynamics are such that a change in the translational acceleration perturbs the compensation, causing the node lines to rotate back toward alignment with the mass unbalance. In operation in an open-loop mode, the rotation of the node lines can be deduced from the amplitude and phase relationships among the outputs of the capacitive vibration sensors. Alternatively, the device can be operated in a closed-loop mode in which the signals are processed into feedback control signals that adjust the electrostatic force to keep the node lines from rotating; in this case, the feedback control signal serves as an indication of the angular velocity or translational acceleration. It is possible to measure rotation and translational acceleration simultaneously and separately because the translation- and rotation-related capacitive-sensor outputs come out in quadrature with each other.

This work was done by Roman Gutierrez and Tony K. Tang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL; (818) 354-5179. Refer to NPO-20620.



A **Planar Resonator** that resembles a four-leaf clover is symmetrical except for a small mass imbalance at the location of the circle. The node lines of the degenerate vibrational modes lie along one or the other set of dashed lines, depending on whether or not the mass unbalance is compensated electrostatically.

Servoamplifier with PCM

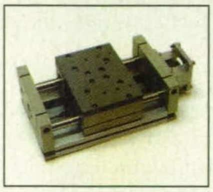
Copley Controls Corp., Westwood, MA, offers the Model 7429DC servoamplifier to drive AC brushless motors rated to 2.5 HP. Designed to operate with the Delta/Tau PMAC2™ controller cards, the unit is under the direct command of the controller, which issues digital pulse width modulation (PWM) signals to the amplifier's motor-powering IGBT bridge circuits. The Model 7429DC operates from power supplies ranging from 45 to 375 VDC and develops ±20 A peak and ±10 A continuous current for driving motors. The PWM commands establish the correct sequence of U, V, and W drive currents for precise control, Copley says, of motor acceleration, speed, and torque.

For More Information Circle No. 737

Hollow Shafted Motors

Empire Magnetics, Rohnert Park, CA, introduces the Size 42 hollow shaft stepper motor, which the company says offer unique processing and packaging advantages for a variety of applications. With a nominal outer dimension of 4.2 in., the motors have a power range of 240-700 W and a torque range of 400-600 oz.-in. Empire points out that fibers can be wound into complex, high-strength patterns as the bundle passes through the motor's center, and manipulator and robot arm designers can pass a linear actuator through the motor to perform mechanical functions in a limited space. Other applications include laser scanning and bundle filament wrapping.

For More Information Circle No. 738



Linear Positioning Stages

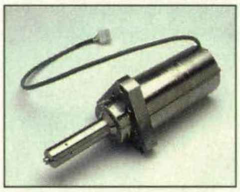
The new TwinTrac™ series linear positioning stages from Distributed Motion LLC, Petaluma, CA, an ASI company, are designed for applications that benefit from economical leadscrew drive and round rail bearing support, the company says. TwinTrac stages can be driven by any NEMA 23 motor, have accuracy ratings to 0.0006 in./in. and achieve speeds up to 20 in./sec. Options include a single motor and I/O connector, end-of-travel and home-limit switches, and various encoder feedback features. The company says typical applications include pick-and-place, inspection equipment, semiconductor manufacturing and test equipment, and machine automation.

For More Information Circle No. 739

Multiaxis Stepper Motor Controller

Trio Motion Technology, Gloucester, UK, announces the Euro 205 one- to four-axis servo/stepper motor controller. The company says that the CE-compliant Eurocard controller uses field-programmable gate array technology and measures only 170 × 29 × 25 mm. Any configuration of servo- and stepper-motor axes can be selected with a simple software change. A fifth axis can be added on an expansion connector that takes standard Trio Motion axis and communications daughterboards. The unit has 24 optoisolated digital I/O on board (16 inputs and 8 outputs).

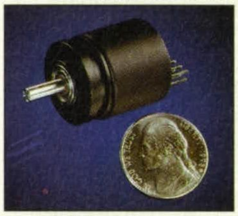
For More Information Circle No. 740



Air-Bearing Disk Spindle

Speedring Systems, Rochester Hills, MI, a subsidiary of Axsys Technologies, offers the DS100 air bearing spindle that the company says has numerous performance advantages. According to Speedring, structural continuity in spindle design and using electroless nickel-plated components, as opposed to the anodized parts traditionally used, results in exceptionally low RF noise. Coupled with double-plane admission air bearings, the DS100 has high tolerance for load imbalance. The company says the AC-coupled encoder performs flawlessly at speeds down to one RPM.

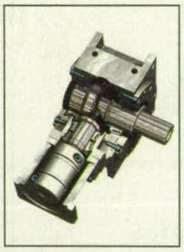
For More Information Circle No. 741



Encoders with 20-mm Diameters

Schmitz Engineering, Burlington, WI, introduces encoders whose sensing scheme embodies a much simplified design, it says, resulting in longer service life and less down time due to feedback device failure. Schmitz says the devices' interlaced silicon photodiode sensors with integral reticle improve sensor and code-wheel alignment tolerance. Code-wheel light transfer attributes and mechanical system inconstancies become less of an issue and result in lower material costs, Schmitz says, and high tolerance of mechanical system change and contamination increases reliability.

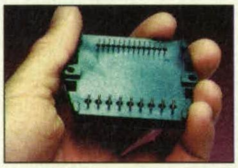
For More Information Circle No. 742



Servo Gearbox

Gam, Chicago, IL, says that its newly released Dyna Series servo gearboxes use unique hypoid gearing to deliver high torque throughput and positioning accuracy for high-dynamic servo applications. The Dyna Series can withstand high input speeds with a backlash of 4 arcmin standard and a backlash of ≤2 available. Eight ratios from 3:1 to 15:1 are offered, with one or two output shafts or with a hollow bore configuration. Additional benefits, according to the company, are the precision-ground gears that allow efficiencies up to 96 percent and provide for low backlash and noise, low inertia and a small profile.

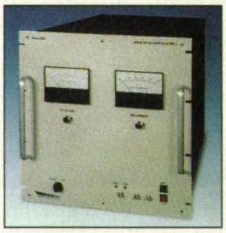
For More Information Circle No. 743



Small Stepping Motor Driver

Intelligent Motion Systems (IMS), Marlborough, CT, is offering the IM805H 7-amp stepping motor driver that, according to the company, utilizes advanced hybrid technology to reduce the size to 2.6 × 2.1 × 0.36 in., making it the world's smallest 7-amp driver. It has an input voltage of +24-75 V and an output current of 1-5 A RMS (7 A peak). The IM805H has 14 built-in microstep resolutions from one-half step to 1/256 step, both binary and decimal. It is designed to be soldered directly onto a PC board, eliminating the need for wiring and mounting. IMS says that proprietary patented circuits reduce ripple current and thus motor heating.

For More Information Circle No. 744



30-kW Power Supply

Diversified Technologies Inc., Bedford, MA, has introduced the PowerMod™ HVPS-30 high-voltage power supply. Providing power up to 30 kW, the DC solid-state unit is designed for magnet control, ion implementation, magnetron heating, lasers, electron beams, RF transmitters, and other demanding applications. It features switching speeds up to 200 kHz, and has less than 1 percent voltage regulation and less than 0.1 percent ripple. It is housed in a standard 19-in. rack mount chassis, and has full over-voltage and over-current protection.

For More Information Circle No. 745

Motors with Ceramic Magnets

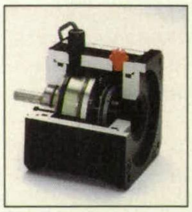
Industrial Indexing Systems, Victor, NY, announces the B Series line of motors for its Delta product line. Designed for applications requiring heavier rotor inertia to optimize servo performance, the motors are suited for direct-drive or toothed timing-belt-drive applications. Their magnets are ceramic rather than rare-earth, making them more cost-effective, the company says. They are available in nine sizes from 380 to 5600 W; all sizes have a rated speed of 3000 rpm and a maximum speed of 4000 rpm. They come with a resolver accurate to ±20 arcmin or with an encoder.

For More Information Circle No. 746

Rotary Servo Actuator

Litton Poly-Scientific, Blacksburg, VA, has added the Model 808-01 rotary servo actuator to its 808 Series of actuators. It features four brush permanent-magnet DC motors controlled by a pulse-width-modulated amplifier with a hybrid power output stage. The actuator, a completely self-contained servo, includes a film feedback transducer, EMI filtering, and a stainless steel power geartrain. It can be configured to accept inputs of either a radio-control-type command or an analog or digital command. The feedback format is a ±10 VDC analog output with voltage proportional to the angular output of the actuator shaft.

For More Information Circle No. 747



Brakes for Stepper/Servo Motors

Electroid Co., Springfield, NJ, offers its SSB series of six front-end brakes specifically designed for braking applications on stepper and servo motors. The device has a zero-backlash permanent-magnet brake and a torsionally rigid coupling to accept misalignment. Available for NEMA 23, 34, and 42 sizes, the brakes also feature dual preloaded sealed bearings that permit greater overhung loads created by drive-belt pulleys, chain sprockets, and gearheads. The brakes are available in 24- and 90-VDC configurations. The company recommends the brakes for industrial applications such as robotics, linear and rotary actuators, and material handling.

For More Information Circle No. 748

LITERATURE & WEB SITE SPOTLIGHT

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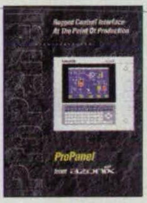

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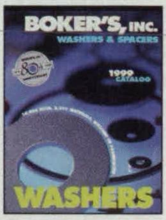

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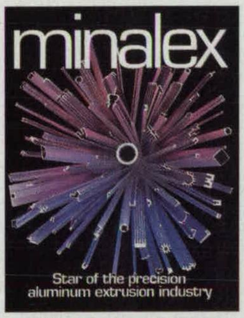

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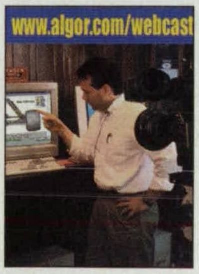

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For More Information Circle No. 631

WAVE/COMPRESSION SPRING CATALOG

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For More Information Circle No. 634

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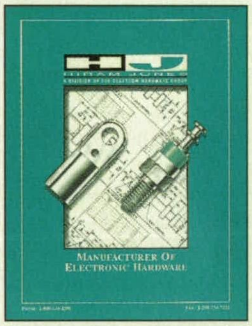

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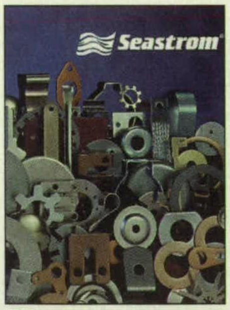

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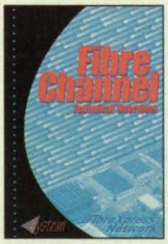

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Firestone Industrial Products Company offers a revised version of its Engineering Manual and Design Guide for Airstroke® actuators and Airmount® isolators. The free manual provides updated guidelines and specs for the air springs, including height, force, and stroke data. Also included are examples of typical isolation and actuation problems that can be solved by using air springs. Firestone Industrial Products Co., 12650 Hamilton Crossing Blvd., Carmel, IN 46032; Tel: 800-888-0650; www.firestoneindustrial.com

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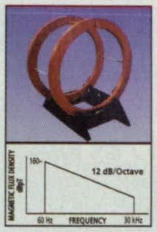

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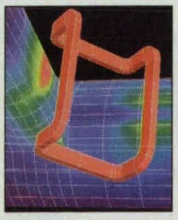

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New on the MARKET

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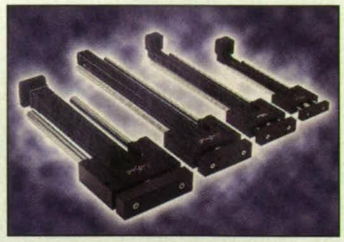
Arc Machines, Pacoima, CA, has introduced a 400-amp, TIG (GTAW) power supply designed to operate the company's orbital weld heads for fusion welding of thin-wall tube and heavy-duty welding of boiler tube, large-bore piping, and vessels. It also adapts to custom-designed fixtures and competitive weld heads. Features include a PC-based, touch-screen display and Windows 95 operating system. The power supply can interface with computer inputs such as bar-coding, and offers real-time data acquisition. Applications include in-place welding and factory automation work-cells. **Circle No. 712**

Screw Actuators



Axidyne® GSA Series actuators from Tol-O-Matic, Hamel, MN, are designed for applications requiring high thrust capacities, high rigidity, and low deflection. Features include a pre-engineered, self-contained guidance and support system of two hardened and ground guide shafts with four internally lubricated ball bearings. Four body sizes are available, from 0.75-2.00", with a choice of reverse parallel or in-line motor configuration. Three different screw sizes range from 0.375-0.750", with solid ACME, solid bronze, or ball nut configuration. Thrust capabilities range from 70-2500 pounds. **Circle No. 713**

Synchronous Controller

Drive Control Systems, Minneapolis, MN, offers the MS332 Synchronous Controller for use with AC and DC variable speed drives in advanced motor-control systems. The unit is designed to monitor performance trends, and make on-the-fly speed adjustments. During set-up, an Auto-Teach function automatically calculates the exact speed ratio between lead and follower systems. The Machine Trending feature monitors machine operation and fine-tunes speeds to compensate for system imperfections. Programmable Event "Phase" Matching allows the user to select an event skip pattern for flexibility during changeover of motion devices such as rotary cutters. **Circle No. 714**

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The FlexSwitch® FLT Series from Fluid Components Intl. (FCI), San Marcos, CA, is designed to perform flow or level sensing simultaneously with temperature measurement. The instrument complies with process-industry precision requirements for point level and interface sensing in liquid, gas, or foam. It is intended for heavy-duty industrial environments (FLT93S) and small process connections requiring a fast, high responsive switch (FLT93F). Applications include wet/dry detection, sump-level detection, high/low level alarm and control, interface control in separation vessels, foam and sediment interface control, and agitation detection. **Circle No. 715**

Infrared Thermometer

The Pyrofiber® fiber-optic, automatic emissivity-correcting IR thermometer from Pyrometer Instrument, Northvale, NJ, utilizes a patented pulse-laser technology to measure infrared radiance while simultaneously measuring and correcting for emissivity. The thermometer provides accuracy within ±5°F. Several temperature models between 500°F-5,400°F are available, with target size ranges between 0.040"-2.300 diameter at focal distance from 4"-120". Custom fiber-optic sensor applications are available. An additional feature measures reflective radiance from extraneous sources, eliminating additional error. **Circle No. 719**

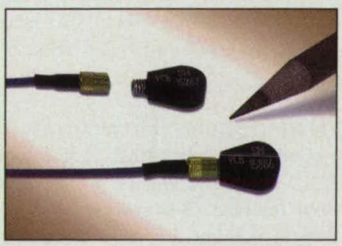
Indexing Mechanisms

J.W. Winco, New Berlin, WI, has introduced new spring and indexing plungers, indexing mechanisms, and control knobs for the manufacturing and equipment industries. Spring, ball, and indexing plungers are used to position, locate, index, and secure parts into place. Plungers come in inch and metric sizes. Materials include steel, stainless steel, and nylon plastic. Variations include plain and threaded bodies; plate mount; push-fit, or weldable; short or standard length; and lock-out or non-lock-out. Indexing mechanisms and control knobs are made of steel and zinc die-cast; they are available in knurled housing or lever types. **Circle No. 720**

Analog/Digital Signal Generators

Hewlett-Packard, Palo Alto, CA, has extended its family of HP ESG RF signal generators. The HP ESG-AP (analog) and the HP ESG-DP (digital) series each consists of four models designed to provide high spectral purity. The HP ESG-AP's analog modulation capabilities include amplitude, frequency, phase and pulse modulation, built-in step-sweep features, and a versatile function generator. The HP ESG-DP series is targeted for general-purpose design and test of wireless components and subsystems. It provides the capability to develop existing and evolving digital communications standards. Both new series span 250 kHz to 1 GHz, 2 GHz, 3 GHz, or 4 GHz. **Circle No. 716**

Miniature Accelerometer



The Model 352C22 accelerometer from PCB Piezotronics, Depew, NY, is designed to offer the convenience of a removable cable in a small, lightweight package. Features include an all-welded aluminum housing and a threaded coaxial electrical connector. Applications include vibration analysis and drop testing of objects such as printed circuit boards, disk-drive assemblies, thin-walled structures, and miniature components. The device weighs 1/2 gram and utilizes a high-output, shear mode, piezo-ceramic sensing element. The unit is designed for adhesive mounting and comes with a 3-56 threaded electrical connector that enables field replacement of the supplied 10-foot coaxial cable. **Circle No. 718**

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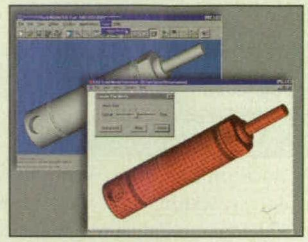
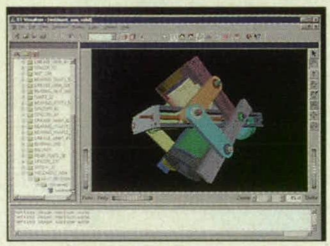
New on DISK

FEA Software Connects to Pro/ENGINEER



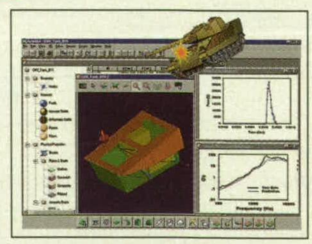
Algor, Inc., Pittsburgh, PA, has introduced InCADPlus technology, which allows seamless transfer of solid-model data from Pro/ENGINEER Release 20 from Parametric Technology Corp. The InCADPlus interface connects Algor's entire range of FEA capabilities directly to Pro/ENGINEER. These capabilities include performing Mechanical Event Simulation (MES) on complete Pro/ENGINEER solid models or assemblies using Algor's Accupak/VE MES software with linear and nonlinear material models. New kinematic elements reduce processing time for MES involving solid models or assemblies. A sliding mesh control enables users to quickly adjust surface mesh density. **Circle No. 728**

3D Visualization Tool



STEP Tools, Troy, NY, has introduced Version 3.0 of ST-Visualizer™ viewer for Windows NT 9/x platforms. This interactive 3D visualization tool is designed to display wireframe and solid model geometry in STEP (Standard for Product Data Exchange) part files. The viewer can be used by CAD/CAM/CAE software developers or by companies developing their own vertical design/manufacturing applications. Version 3.0 features include support for assemblies, AP-214 (STEP-Version 2) application protocols, and automatic shading of 3D components. **Circle No. 731**

Shock and Vibration Analysis



AutoSEA SHOCK 1.0 from Vibro-Acoustic Sciences, San Diego, CA, is a transient and impulsive response module for AutoSEA2 CAE software. The module is designed to allow users to extend the use of AutoSEA2 modules to the prediction of shock. Applications include the shock response of military structures due to ballistic impact and explosions, as well as pyrotechnic shock response in aerospace vehicles. Features include a Shock Solution wizard, which runs as a fully integrated part of AutoSEA2. A Shock Load Library includes rectangular, triangular, half-sine, polygon, ramp-exponential, and arbitrary load inputs. **Circle No. 733**

Heat Transfer/Flow Analysis

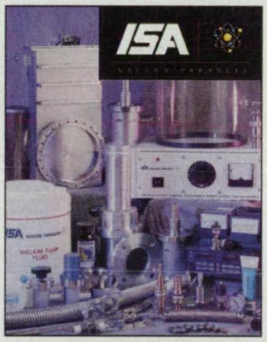
Cullimore and Ring Technologies, Littleton, CO, has released SINDA/FLUINT version 4.1, a NASA-standard heat-transfer and fluid-flow analyzer. The program has been revised for liquid propulsion design, making the code useful for two-phase hydrodynamic events such as pogo suppression, latch valve waterhammer, and line filling. Enhancements include the iface network element, which allows subdivision of quasi-stagnant control volumes. The ability to model temperature and pressure differences between liquid and gas phases within quasi-stagnant control volumes has been extended to any part of the flow, including pipe flow. The software includes fluid-to-fluid heat transfer tools for modeling conduction within the fluid. **Circle No. 730**

New LITERATURE

Materials Reference CD

DuPont Microcircuit Materials, Research Triangle Park, NC, offers a CD-ROM of the thick film and Green Tape™ Resource Library. Contents include applications information, product data sheets, and design guides for using and processing thick film and Green Tape materials. It also covers polymer thick film materials for membrane touch switches, shielding and through-hole plugs for PWBs, and electroluminescent materials. **Circle No. 723**

Vacuum Technology

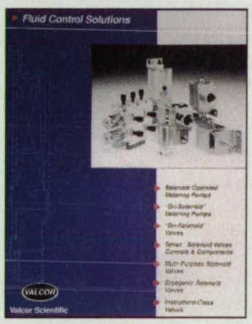


ISA Vacuum Products, Norwalk, CT, has released a 100-page catalog of vacuum technology products for the aerospace, semiconductor, pharmaceutical, and chemical industries. Products and services include refurbishing/upgrading existing systems; custom engineered high-vacuum systems; valves, traps, and baffles; thermocouple gauges and tubes; ion gauge controllers and tubes; mechanical pumps; vacuum fluids; sputtering targets, liners, and evaporation materials; and emitter rebuilding. **Circle No. 722**

Level and Flow Measurement

A 15-page brochure from Drexelbrook Engineering, Horsham, PA, describes level measurement and control devices such as RF and ultrasonic point level controls, RF continuous level transmitters, smart level transmitters for digital communications and remote calibration, and RF sensors. The brochure also includes a selection chart for point-level and continuous-level products. **Circle No. 724**

Pumps and Valves



VALCOR Scientific, a division of VALCOR Engineering Corp., Springfield, NJ, offers a 6-page brochure describing solenoid pumps and valves. These products are suitable for new and retrofit applications, including analytical and biochemical instrumentation; medical and pharmaceutical; semiconductor and related telecommunications industries; and a variety of light industrial uses. **Circle No. 721**

Silicone Adhesives and Sealants

A two-page application selector guide on silicone adhesives, sealants, and potting compounds is available from Master Bond, Hackensack, NJ. The guide includes one- and two-component systems, and shows viscosity, tensile strength, elongation, hardness, cure schedules, service operating temperature ranges, and application recommendations for 22 different grades. **Circle No. 725**

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Use the phone numbers listed below to obtain more information from the following companies featured editorially in this issue.

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The AGATE Program: The Next Revolution in General Aviation

In Part I of the NASA Business Forum preview last month, we focused on space development in the new millennium, and how NASA's Kennedy Space Center is leading the way with Vision Spaceport. In this month's Part II, we look at General Aviation, another featured topic of the NASA Business Forum, which is part of the NASA-sponsored Technology 2009 national technology transfer conference to be held November 1-3 at the Fontainebleau Hilton in Miami Beach.

General aviation is in the forefront in developing advanced technologies for the entire aviation sector, and eventually will help pave the way for the convergence of air and space transportation in the new millennium. A major part of that predicted revolution in general aviation is the AGATE program, the focus of this month's article.

"Looking forward 25 years, beyond saturation of the national highway and skyway systems (gridlock and hublock), the nation faces new challenges in creating transportation-driven economic growth and wealth," according to Dr. Bruce Holmes, manager of NASA's General Aviation Program at Langley Research Center in Hampton, VA. "For this new economy to reach its full potential," said Holmes, "a new transportation system is required."

The Advanced General Aviation Transport Experiment (AGATE) program is that new system — a cost-sharing industry, university, and government partnership initiated by NASA to develop the technological basis for revitalization of the U.S. general aviation (GA) industry. AGATE was founded in 1994 to develop affordable new technology, as well as industry standards and certification methods, for airframe, cockpit, flight training systems, and airspace infrastructure for next-generation, single-pilot, near-all-weather light airplanes. The AGATE Consortium has more than 70 members from industry, universities, the Federal Aviation Administration (FAA), and other government agencies.

AGATE is part of NASA's Advanced Subsonic Transport (AST) Program, and is organized into the following ten technical project areas:

- *Flight Systems* — Develop affordable flight systems that allow near-all-weather flying for light GA airplanes; intuitive cockpit display technologies that provide improved situational awareness, and weather and traffic information to the pilot; and guidelines and certification standards for these technologies.
- *Propulsion Sensors and Controls* — Develop design guidelines and certification standards for electronic engine controls and diagnostics that provide lower direct operating cost, reduce emissions, and lower noise.
- *Ice Protection Systems* — Develop design guidelines and certification standards for new ice protection systems that are compatible with laminar flow wings; and conduct research to improve airframe ice formation prediction models.
- *Integrated Design and Manufacturing* — Work to reduce airframe and propeller cost and weight by using low-cost design and manufacturing methods; non-destructive testing; and composite material properties.

Dr. Bruce J. Holmes, Manager, NASA's General Aviation Program, will be a featured speaker at the NASA Business Forum in Miami Beach on Tuesday, November 2.

- *AGATE Integration Platforms* — Develop and conduct simulation and flight test tasks with mature projects emerging from the other AGATE project areas.
- *Flight Training Curriculum* — Develop and validate advanced training technologies and techniques that take advantage of integrated cockpits, and single-lever power control.
- *National Airspace Infrastructure* — Develop an air and ground infrastructure for small planes that fits into the FAA's new airspace plans: Flight 2000 and Free Flight.
- *Program Assurance, Systems Assurance, and Program Analysis* — Ensure that technology development, design guidelines, and certification standards work progress within the AGATE project areas.

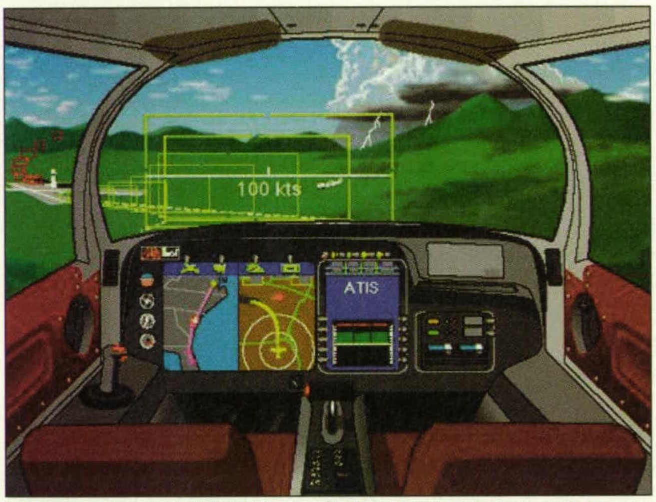
NASA, along with the FAA, leads the National General Aviation Roadmap strategy, which guides national investments towards an "InterState Skyway" capability. The Small Aircraft Transportation System (SATS) program would be a main component of such a system. SATS is an integrated transportation system that

relieves the current pressures on existing ground and air systems, land use, and environmental concerns.

The goal of General Aviation is to "enable doorstep-to-destination travel at four times the speed of highways, to 25% of the nation's suburban, rural, and remote communities served by public airports in 10 years, and over 90% of those communities in 25 years." What this means is that every community or county outside of a 50-mile radius of a hub-spoke airport will be served by a SATS-compliant airport with SATS-compliant aircraft available within a 30-mile radius.

The Roadmap also provides the framework for public and private partnerships that target investments in strategically relevant, enabling technologies. So far, investments have been focused on air vehicle and operator training technologies for revitalizing the General Aviation industry. The next step involves planning investments in infrastructure technologies, along with the next phase of vehicle technologies. Together, these investments create the basis for SATS.

During the past five years, AGATE and the General Aviation Propulsion (GAP) NASA-led public-private partnerships have been implemented to support the Roadmap. By 2001, AGATE and GAP programs will complete the development of advancements in the areas of engine, avionics, airframe, and pilot training technologies.



New space-based Global Positioning System (GPS) navigation devices, coupled with new display technologies, will depict intended and actual flight paths for easier navigation. This cockpit design includes a single-lever power control, automobile-like control switches and dials, and a "moving map" navigation display.

The SATS Concept

According to Holmes, the SATS concept is defined as:

- An integrated transportation system approach to safety for small aircraft, underutilized airspace, and small landing facilities.
- Affordable infrastructure for highly accurate instrument approaches to virtually all runway ends and helipads in the nation.
- Scheduled, as well as on-demand, point-to-point air transportation services among 5,400 public-use landing facilities (current scheduled air carriers serve only about 660 of these facilities).
- Safe accessibility by air to 90% more destinations throughout the nation.
- Economic development for suburban, rural, and remote America, enabled by SATS transportation innovations.
- An exportable transportation innovation of significant economic impact for the nation's balance of trade.
- An affordable means to close the 21st century gap between transportation demand and supply.

Studies indicate that highway construction generates more traffic, rather than alleviating traffic, raising congestion levels. Similar conditions are arising in the hub-and-spoke air transportation system. As the nation moves into the first decade of the 21st century, transportation demands are growing. For example, explained Holmes, the hub-and-spoke airport infrastructure will be in its saturation phase — or in "hub-lock" — by as early as 2008.

NASA Administrator Daniel S. Goldin, in a recent speech to the American Bar Association Forum on Air and Space in Chicago, said that NASA views a full-scale revolution in general aviation as a national priority, and that the agency has "committed to reprogram $500 million of the aviation enterprise's budget over five years" to this purpose. Said Goldin, "If the number of airline passengers doubles over the next 20 years as expected, our current hub-and-spoke aviation system will face hub-lock. Same-day flight will be a thing of the past. Instead, we may have to put our names on waiting lists, like at today's restaurants. One airline has predicted it could happen as early as 2012."

The value of human time and the related issue of quality of life also will become more important. "The new value of time makes doorstep-to-destination speed the premium commodity during this new era," according to Holmes. This desire for transportation innovations "must be satisfied while maintaining safety, affordability, and convenience for the customer," he said. "The public requirements for national airspace capacity, efficiency, cost, and environmental compatibility of operations must be met."

"The ingredients for a significant advancement in transportation are in place," according to Holmes. "Realization of this advancement will require that the nation meet the challenges of making small aircraft and small airports more accessible to greater numbers of the traveling public. Today's small airports represent a grossly underutilized national asset. A current available set of enabling vehicle technologies includes a new generation of engines, avionics, airframe, navigation, communication, and operator training for a new generation of small transportation aircraft."

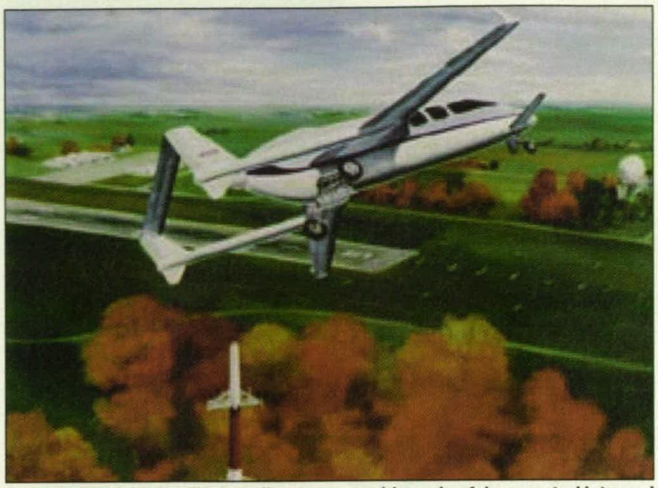
A goal is to enable the development of small aircraft that are superior to automobiles for intercity trips of 150 to 1,000 miles. In the near-term, this means the creation of a new generation of safe, affordable, quiet, and easy-to-fly transportation light planes; the potential for increased National Airspace System (NAS) capacity by expanding the use of existing, underutilized airports; and expanding the use of existing general aviation aircraft.

Operations and Architecture

The operational concept of the program utilizes small aircraft for personal and business transportation, for point-to-point direct travel between smaller regional, general aviation, and other landing facilities, including heliports. The AGATE aircraft represent the air vehicles of the future that will operate along the airborne version of the current national highway system.

The program architecture contemplates landing facilities that would be upgraded to provide near-all-weather utility. In addition, the facilities would not necessarily require control towers or radar surveillance. More than 18,000 landing facilities serve communities in the US; ultimately, virtually all of these facilities could employ SATS operating capabilities, according to Holmes.

SATS aircraft will be primarily single-engine, single-pilot-operated craft in near-all-weather conditions, with a significant fleet of light, twin-engine aircraft as well. Since the SATS infrastructure requirements for fixed-wing aircraft are compatible with those for rotorcraft, vertical flight configurations also would comprise a portion of the fleet. Said Holmes, the aircraft will incorporate "state-of-the-art advancements in avionics, airframes, engines, and pilot training, and be capable of operating in free flight



The AGATE aircraft will be easily maneuverable and safely operated into and from many available airfields in the U.S. The general aviation airfields throughout the country will be equipped for all-weather operations, meeting AGATE aircraft performance capabilities.

modes within the evolving National Airspace System. The Free Flight environment allows pilots to choose their own routes, regardless of weather conditions, depending upon their skills, qualifications, and aircraft capabilities.

Major elements that comprise the SATS infrastructure include:

- Highway in the Sky (HITS) graphical flightpath operating systems, including graphical weather, navigation, traffic, terrain, and airspace depictions that increase safety, utility, and ease of flying. Pilots would have access to HITS in marginal weather for all runway ends and helipads, enabling them to safely determine routes, speeds, and proximity to adverse weather conditions and other aircraft. The HITS systems also include full-featured auto-pilots to relieve pilot workload, enable 4D navigation, and provide backup in times of emergency.
- Flight Information Services (FIS), broadcast by terrestrial or satellite systems, and Traffic Information Services (TIS), broadcast by aircraft, terrestrial, or satellite systems.
- Airports with 3,500- to 5,000-foot runways and helipads, with only necessary lighting and marking, and without towers or radar surveillance.
- Airports within a 15-minute drive of the communities served.
- Small aircraft that is operated personally or with hired pilots, serving the personal and business demands of typically between two and three passengers per departure.
- New, quiet engines that burn unleaded fuel, with simplified controls (single-lever power controls) and intuitive diagnostics; and crashworthy airframes with airbags and, in some vehicles, whole-aircraft parachutes.
- Cruise altitudes from 6,000 to 25,000 feet; speeds of at least 200 to 300 knots; and full-fuel ranges between 800 and 1,200 nautical miles.
- Simple and affordable pilot training through technologies such as Internet-based and simulation-enhanced training systems; and training time and cost commensurate with public school implementation of "fliers' education," in addition to drivers' education.

AGATE aircraft and its successors represent the air vehicles of the future that will operate along the airborne version of our current national highway system. Just as safe, but faster and more economical than ground vehicles, the AGATE aircraft will provide travelers with another alternative for personal and business travel.

How the Public Benefits

"Through intelligent design, the potential exists to greatly exploit the benefits of a faster, distributed air transportation system for rural communities with minimal impact on the capacity of airspace and airports by large aircraft today," explained Holmes. The anticipated public benefits accrue from "increased mobility for citizens traveling throughout the nation, and accessibility for vastly more of the nation's communities." In addition, benefits in the form of safety, cost, airspace efficiency and environmental effects would be recognized. "The SATS operating capabilities will also benefit and serve the needs of small cargo providers, public service aviation, law enforcement, disaster relief, and emergency medical services," said Holmes.

The benefits of the system for the public are expected in four areas: personal/business, community/airport, regional/state, and national.

- *Personal/Business.* These benefits would derive directly from the effects of the reduced cost of air travel, by enabling access to air transportation at about half the cost of current regional carrier prices for people living in remote areas. SATS would increase the individual's range of mobility, improving access to family and business opportunities.
- *Community/Airport.* SATS would enhance a community's ability to attract economic development, by providing new, competi-

(Continued on page 8c)

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(Continued from page 4c)
tively priced travel alternatives. Benefits would be enabled by upgrades to increase the utility of a community's existing airport, drawing new knowledge-based industrial development.

- *Regional/State.* In the next seven to ten years, SATS deployment could more than double the number of communities with air transportation, according to Holmes. Regional and state benefits derive from the increased accessibility throughout smaller travel markets that otherwise would be underserved by highways and the hub-and-spoke airport system. SATS also has the ability to increase the effectiveness and affordability of state-provided public services, including disaster relief, emergency services, and law enforcement services.
- *National.* In the longer term, SATS may increase ten-fold the communities with air transportation. SATS could affect land use and land value by increasing the utility of existing small airport infrastructures.

To obtain these benefits, a significant national public education challenge must be met, said Holmes. "Public comprehension of the potential for personal and societal benefits that accrue from SATS transportation capabilities will accelerate public policy funding to support deployment of SATS infrastructure."

To gain pubic support, a federal-states partnership could design and deploy SATS transportation system demonstration projects within selected travel markets. The demonstrations would begin with SATS consumer analyses to quantify the market, potential traffic, and technology priorities. These analyses, leading to demonstrations, already have been contemplated in NASA's proposed planning for the SATS program. The information collected would form the basis for public policies addressing issues of airport noise standards, land use, and safety.

What public sector requirements must be satisfied for a SATS system to flourish in the next century? According to Holmes, public sector issues for SATS must follow the path from public education, to public opinion, to public policy, to pubic laws, to public funding. "Therefore," said Holmes, "the National Research Council is developing a committee to study the SATS concept. This project will evaluate trends and forces that shape 21st century demand for higher-speed personal air transportation, and provide guidance to NASA and other federal and state government partners for SATS investment and partnership planning."

Administrator Goldin sees the program as a way to revitalize America's general aviation sector. "Imagine what a full-scale revolution in general aviation would do. We might move toward inexpensive fleets of business jets, and when they are retired from executive service, they may be sold to fractional partnerships, then later recycled into fleets of air taxis and jet pooling. The possibilities are endless," said Goldin.

According to Holmes, the SATS concept has the potential to help close the gap between 21st century transportation demand and supply. "SATS mitigates the restraints to growth imposed by gridlock, hublock, and urban sprawl, while reducing economic disparities imposed by the concentrated transportation systems of the 20th century." Holmes concluded that "SATS increases the radius of action of daily life by ten-fold — the first increase of such magnitude since the cars displaced horses for intercity travel."

For more information on the AGATE program and the Small Aircraft Transportation System (SATS), contact Bruce Holmes, Program Manager, NASA's Langley Research Center, Hampton, VA, at b.j.holmes@larc.nasa.gov, or visit the AGATE web site at: http://agate.larc.nasa.gov/. For more information on the NASA Business Forum and Tech East '99, visit www.techeast.net.